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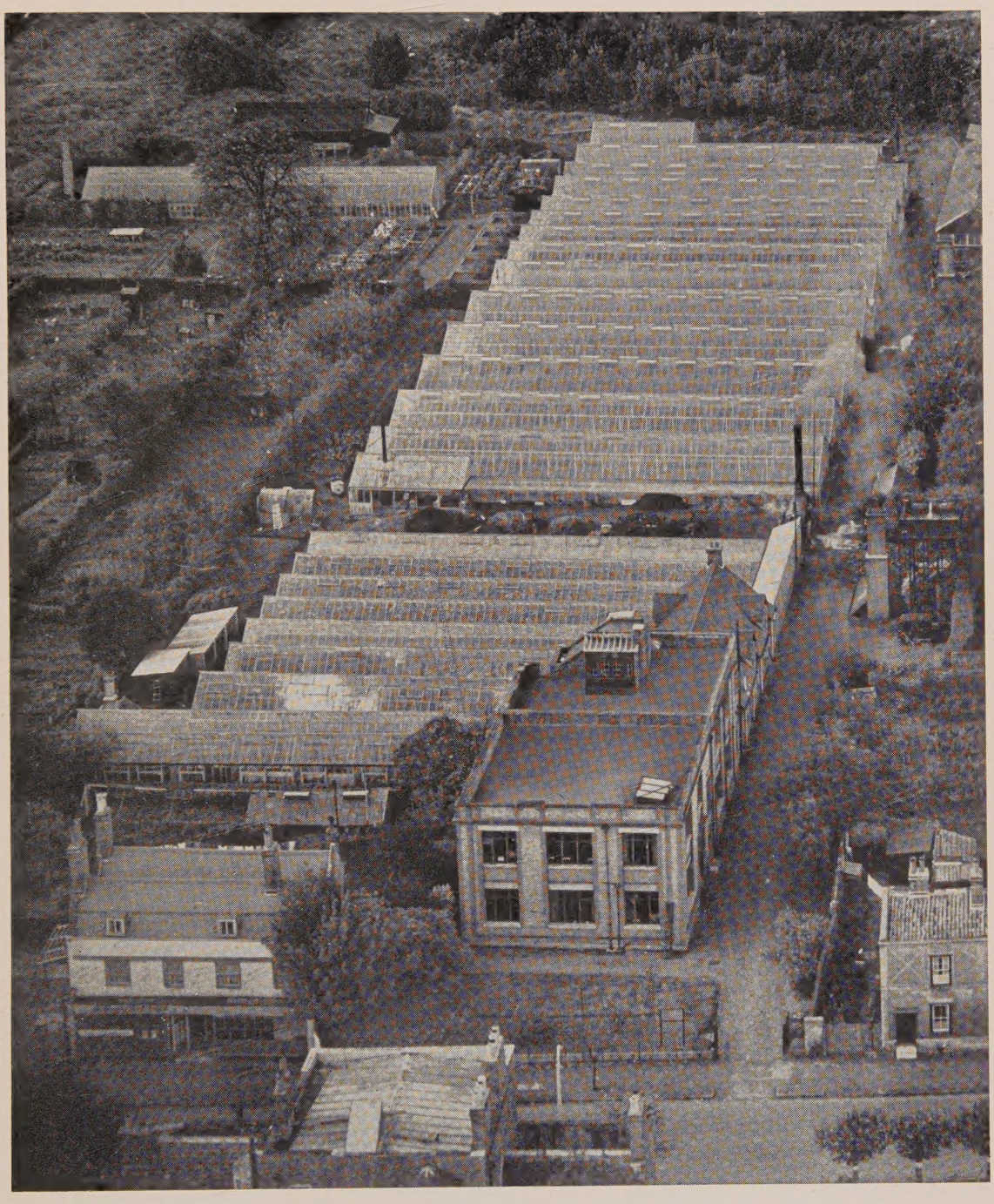

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INTRODUCTION

It is a pleasure to report that the work of the Research Station continues to make steady progress despite the congested state of the laboratories and the unstable condition of the glasshouses. The development of the new site near Littlehampton has not yet materialised, although something may happen before this report is published. Let us hope the work of construction, once started, will proceed with all speed.

GLASSHOUSE EXPERIMENTS

Planting Density and Crop Yield of Tomatoes

The standard Lea Valley practice of allowing 16,000 tomato plants per acre was compared with half that density using the variety E.S.1. Total crop yield was practically the same from the two densities, indicating as was found previously, that a tomato plant produces fruit in accordance with the amount of space surrounding it. In other words, the plants at normal spacing distances produced about half the weight per plant of those planted 8,000 to the acre. The fruit was larger and less blotchy at the lower density.

Unfortunately, however, the weight of crop picked in May and June was rather more than 1 ton per acre less from the wider spacing, and when the total value of the crop was computed it showed some £92 per acre in favour of the closer planting.

Labour costs, however, were not taken into consideration but it seems fair to assume that they would be much less in the case of the wider spacing and the problem is one for further investigation.

Deficiency Experiments

The deficiency experiments with regard to nitrogen, phosphate and potash show the same type of result as they have done during the past 30 years, both the unmanured plot and the low potash plot yielding a high proportion of blotchy fruit.

Milled Seaweed

A good sample of dry shredded seaweed, bearing a distinct odour of the fresh product was incorporated in the soil at the rate of 4 ozs. per square yard. Care was taken to wet the soil thoroughly after application but there was no difference in the habit of the plants or on crop yield when compared with the controls.

The Addition of Sulphur to the Soil

This experiment started in 1943 ended this year, when a large proportion of the plants died at the beginning of May in the plot receiving one pound of sulphur to the square yard. Examination of the diseased roots revealed no active parasitic fungi, although the tissues were full of *Penicillium*. Examination of the soil showed considerable variation in pH from place to place, but the average was around 3·40. Death was obviously due to chemical injury.

The general conclusions which arise from the 10 years' results is that under our conditions the reduction in pH within reasonable proportions had no effect either upon crop yield or quality of the fruit. We conclude, further, that the normally high pH value of our soil is not detrimental to the tomato crop.

Steam Sterilization v. D.D.

The effect of injecting the soil with D.D. was compared for the second year with that of steam sterilization. Both were equally effective against the tomato root knot eelworm, *Heterodera marioni*, but the crop yield following steaming was 50 tons per acre as against 40 tons per acre for D.D.

Steam Sterilization v. Formaldehyde and Chloropicrin

This experiment was unsatisfactory because owing to poor light the plants became very rank in the early stages, and the differences in crop yield from the different treatments were too small to be of any value. Steam and chloropicrin gave yields above that of the control but treatment with formaldehyde showed no improvement.

Lime and Phosphate

The experiment started in 1947 to determine the effect of omitting lime and phosphate from the fertilizer treatment was continued for the sixth year. The omission of each singly had no effect upon crop yield, but there was a slight reduction where both were withheld.

Tomato Variety Trials

The tomato trials were continued this year. Aldouri gave the highest yield, otherwise none of the varieties tested proved outstanding.

Cucumbers

Once again injection of the soil with D.D. following steam sterilization gave an excellent control of Root Knot eelworm, *Heterodera marioni*.

An attempt was made to see if better crops could be obtained by using good virgin soil instead of steam sterilized soil in the preparation of the beds. The results of our experiments showed no real differences between the two. Further, the replacement of the usual first top dressing of bone meal by a complete fertilizer showed no improvement.

Carnations

Carnations were grown in four beds. The control bed was placed directly on the ground; another rested on a solid base of bricks, another on a base of 2-in. tiles, while the fourth was placed in a shallow concrete trough, one end of which was well drained and the other poorly drained.

The number of flowers per plant was slightly higher in the beds over bricks and tiles when compared with the control, but the greatest number of flowers was produced in the well-drained half of the concrete trough.

PLANT PATHOLOGY

Didymella Stem Rot of Tomato

A small field trial has been carried out to determine how long steam sterilized soil remains susceptible to infection by *Didymella lycopersici*. Soil was inoculated at intervals over a period of three months after steaming and then planted with tomatoes. It was found that plants in the earlier infected soil became diseased sooner than those in soil inoculated later. Even after three months, however, recontamination of the soil by other organisms was not sufficient to prevent the establishment of *D. lycopersici*. Plants died over a period of four months while several apparently healthy plants were found to be infected at soil level when the experiment ended 250 days after planting.

The growth of several strains of the fungus in different soils has been investigated. Counts showed that some strains increased in numbers when grown in station soil while others did not, although all increased in a maiden loam.

Possible antagonistic reactions between soil microfloras and *D. lycopersici* have been studied. A number of organisms were isolated from two soils, one from a house in which Stem Rot had been severe and one from another where only a slight non-spreading attack had occurred. These organisms were tested for antibiotic action against *D. lycopersici*. The results show that about 30 per cent. of the organisms isolated from each soil were antagonistic to it.

Some inoculation experiments have been carried out using strains of *D. lycopersici* from tomato stems, outdoor tomato fruit and from strawberries. The strains from tomato fruit and strawberry appear incapable of infecting tomato stems but further study is needed before definite conclusions can be drawn.

Other experiments indicate that the fungus can grow 1·0–1·5 mm. into a petiole stub in 48 hours and that wounds remain susceptible to infection for over 24 hours.

Black Stem Rot of Cucumber

Some observations have been made on Black Stem Rot of cucumber caused by *Mycosphaerella citrullina*. Cross inoculations have shown that this fungus can infect cucumber, melon and vegetable marrow, but tomato was not infected.

Tomato Root Rot

Isolations of fungi from root debris left in the soil of steamed and unsteamed plots in the glasshouse after the tomato plants had been removed show:—

(*a*) There is higher percentage infection of dead roots from the unsteamed soil;

(*b*) Debris from the lower soil levels harbours fewer fungi than that from soil nearer the surface.

Colletotrichum atramentarium was recorded only from dead roots in the unsteamed plot.

After air drying the root debris only two of the fungi normally found in tomato roots, *C. atramentarium* and a grey sterile fungus, could be isolated from the dead roots.

A comparison of the organic debris present in soils steamed in different years but cropped continuously indicated that undecomposed residues accumulate in unsteamed soil.

Analysis of the tomato rhizosphere and also the soil from pots in which sterilized soil had been inoculated with different fungi, showed differences in the ability of the fungi to establish themselves in the two regions, and also in the numbers of fungi in different zones of the root system.

Work has been started with root tip cultures of tomato to investigate the possibility of antagonistic action of fungi to root growth in vitro.

Virus Diseases

The virus work consisted of research on chrysanthemum mosaic and therapeutic means of control. Clean chrysanthemum plants made more susceptible by heat treatment were infected with chrysanthemum mosaic virus by mechanical inoculation. Attempts to clean mosaic infected chrysanthemum stools and plants by heat treatment proved unsuccessful.

Further work on the heat treatment of Arum Lily corms was done but a complete cure was not obtained. Of 10 chemicals either applied to the root system of chrysanthemum plants or sprayed over the foliage only one—2, 4-dichlorophenoxy acetic-acid—showed any indication that chemical control was possible. One sample of virus infected tomato seed was treated with short wave radiation and another sample with super-sonic radiation. Only the former produced any destruction of virus, and in no case was there any effect on the seed itself.

ENTOMOLOGY

Red Spider Mite

A study has been made of the external anatomy of the mite in all stages of its development from microscope preparations; and of the internal anatomy, with special reference to the organs of digestion and excretion, of the adult from serial sections.

Submergence in water of female mites in the deuteronymph resting-stage for periods of 24 to 72 hours did not materially affect the subsequent span of life or reproductive capacity of the adults. Some observations upon the retention of air in the spiracles of mites submerged respectively in water and in a dilute solution of estol were recorded.

A considerable proportion of eggs deposited and kept in a totally dry atmosphere and in one of 50 per cent. relative humidity hatched successfully.

In comparative experiments in which adult female mites were kept respectively upon the foliage of growing plants and upon leaf-discs floated on water, the reproductive capacity was much greater but the span of life rather less under the former than under the latter conditions; there was however, great individual variation in the total number of eggs deposited, irrespective of these conditions.

Mites reciprocally transferred between tomato and carnation and those transferred to tomato after having been reared upon cucumber laid, on the average far fewer eggs than mites which were interchanged between other combinations of the three kinds of plant.

INSECTICIDES AND FUNGICIDES

Acaricides

Investigations of the ovicidal action of certain chlorinated anils, oximes, phenylhydrazones and chlorophenylhydrazones have been continued with the twofold object of obtaining information on the effect of chemical constitution on ovicidal action towards acarine eggs, and of finding new acaricides of commercial value and low mammalian toxicity.

In view of the difference between the results of tests at Cheshunt and the results obtained in America, the ovicidal activities of certain chlorine substituted phenyl benzenesulphonates have been redetermined by the leaf disc dipping technique. The results obtained confirmed previous results since little difference was found between the potencies of 4-chlorophenyl benzenesulphonate and 4-chlorophenyl 4-chlorobenzenesulphonate.

Glasshouse trials have shown that 4-chlorophenyl benzene-sulphonate is a very promising acaricide for use on tomatoes.

Fungicides

As a result of earlier work with quinones and related compounds, certain substituted amino-phenols and their derivatives have been synthesised and their fungicidal potencies determined in laboratory tests.

Many of these compounds have been examined further in glasshouse trials as eradicant fungicides against tomato leaf-mould and *Didymella* stem rot of tomatoes.

Of the newer fungicides tested against cucumber mildew in glasshouse trials only 6-capryl-2 : 4-dinitrophenyl crotonate was outstanding as a fungicide. Insufficient evidence as to its safety on cucumbers has been acquired so far.

Soil Sterilization

Replicated trials in which chloropicrin, steam and formaldehyde were compared as agents for the partial sterilization of glasshouse soils, showed that under the conditions of the test, chloropicrin was equal to, or better than steam, and superior to formaldehyde.

Insecticide Residues

Investigations concerning residues of toxic chemicals employed as insecticides or fungicides under glass, were greatly hindered by changes in staff. Methods for the determination of parathion in glasshouse food products have been investigated.

SOIL CHEMISTRY

Nitrogenous Fertilizers

As part of a general investigation of nitrogenous fertilizers a wide range of hoof and horn samples has been examined in the laboratory. The experimental methods used were similar to those previously published for bone materials, decomposition of the organic fertilizers in the soil being compared with the results of various chemical and physical tests. It had originally been intended to study these materials in three groups, namely hoof, horn, and commercial mixtures of the two. Preliminary tests soon showed, however, that heat treatment of the samples by the manufacturers altered their properties considerably. The samples were accordingly separated into two groups, all which had received any form of preliminary heat treatment being referred to as "calcined" as distinct from the original raw materials. In order to compare the initial rates of mineralization of nitrogen all the 41 samples were incubated with soil for a period of one week. In the case of the raw samples the initial rates of mineralization thus determined were found to be closely correlated with the bulk density of the milled materials, and with the percentage of the total nitrogen of the samples hydrolysed by dilute sulphuric acid under controlled conditions in an autoclave. Very little of the nitrogen of raw hoof and horn was soluble in water, but a considerably higher content of water-soluble nitrogen, ranging from 2·6 to 29·6 per cent. of the total nitrogen, was found in the calcined samples. In the case of the calcined materials this water-soluble nitrogen proved to be a reliable guide to the initial rates of mineralization of nitrogen in the soil, as also did the bulk densities of the milled materials and their ammonia content.

In contrast to the highly significant correlations found between rates of decomposition in the soil and the various chemical and physical tests employed, no such correlations could be found with the "availability" of the samples as determined by a longer period of incubation in the soil. After incubation for 10 weeks, from 64 to 81 per cent. of the total nitrogen of 22 samples of raw hoof and horn was recovered as ammonia and nitrate in the soil, the corresponding range for 19 samples of the calcined materials being from 62 to 76 per cent. In general, the calcined materials began to nitrify more rapidly than the raw samples, the difference being particularly marked with horn materials, but such differences did not persist for long in the soil. The most obvious effects of the preliminary heat-treatment (calcining) of hoof and horn materials by the manufacturers were found in their increased solubility and bulk density; in particular the tough fibrous nature of raw horn was changed, the calcined materials being easier to crush. In contrast to the bone meals previously investigated, hoof and horn materials constitute a reasonably homogeneous class of nitrogenous fertilizer.

Steam Sterilization

The study of ammonification and nitrification in soil after steam sterilization has been continued. Ammonia and nitrate production and the nitrifying capacity of the soil as measured by incubation with ammonium sulphate have been periodically determined in a glasshouse soil steam sterilized *in situ* and subsequently flooded, base-dressed and planted with tomatoes. These results have been compared with those obtained in two adjacent steamed plots, one of which was flooded and base-dressed but not planted, and the other left undisturbed apart from occasional watering to keep the moisture content reasonably constant. In addition, changes in ammonia and nitrate and in the nitrifying capacity were followed in the propagating and potting mixtures in which the tomatoes were raised before being set out in the glasshouse border.

Before the application of the base-dressing ammonia production was similar in all three steamed plots, and the nitrifying capacity of the soil was very low. Where the soil was flooded some nitrate was washed out, but ammonia concentrations were only slightly affected. Increased ammonia production was observed after the base-dressing was applied on the 95th day after steaming, and the nitrifying capacity of the soil from both base-dressed plots also increased rapidly. Where the soil remained unplanted conversion of the soil ammonia into nitrate was complete seven or eight weeks later. Nitrification was, however, much more rapid in the soil which was planted with tomatoes on the 98th day after steaming, the ammonia disappearing here within three weeks of planting. In contrast, where the soil was undisturbed nitrification did not begin until around the 125th day after steaming when the nitrifying capacity of the soil began to increase slowly. Recolonization of the soil by nitrifying organisms, however, was extremely slow, and a further three months elapsed before the ammonia was completely nitrified.

These results show that the onset of nitrification in a steamed glasshouse soil was accelerated by the application of a base-dressing and also by the planting of tomatoes. That the rapid nitrification in the planted plot was probably due to contamination of the soil by the potting soil adhering to the plants' roots is shown by the results for the soils in which the tomato plants were raised. Ammonia was high in the propagating soil when the seeds were sown, but at this time the soil was nitrifying, and four weeks later when the seedlings were potted up ammonia concentrations were low. Contamination of the potting soil by the actively nitrifying propagating soil seemed to have been followed by the rapid recolonization of the former by nitrifying organisms, for as a result of this the ammonia concentration fell. Subsequently the introduction of the potting soil into the glasshouse border proved an effective source of infection.

Mineral Deficiencies

Investigation of the effects of acute mineral deficiencies on carnations in sand culture has been continued. The deficiencies studied included those of nitrogen, phosphorus, sulphur, potassium, magnesium, calcium, boron, manganese, iron and zinc. Two varieties, White Maytime and Spectrum, have been used in these experiments; marked differences were noted between these varieties in response to the omission of various elements.

The effect of Sulphur on the pH and Carbonate Content of a Tomato Soil

Experiments on the effect of sulphur on a tomato soil, started in 1943, are summarized. The soil used initially contained a considerable amount of calcium carbonate, and in the first years of the experiment changes in pH resulting from sulphur treatments were relatively small. In the later stages of the experiment more marked changes in pH occurred, however, and by 1952 conditions of extreme acidity were reached. The relationship between pH and carbonate content of the soil is discussed, and data presented for the accumulation of soluble salts at the end of the experiment. A high concentration of water-soluble manganese was found in the treated soil.

Soil Analysis

The flame-photometric technique for the rapid estimation of potassium in soil extracts has been introduced in the laboratory.

PLANT PHYSIOLOGY

Dutch Light Temperatures

Observations on air and soil temperatures in the open and under dutch lights have been continued in collaboration with the Agricultural Branch of the Meteorological Office. The cup anemometer on loan from M.O.19 was returned as its readings in the position used were unreliable. A survey of the soil temperature distribution at 2 inches within the lights is being made.

Root Studies

The glass-sided box and glass-lined trench were modified and again used for observations on the growth of the roots of another variety of tomato, under normal cultural treatment. Last year's results on the growth inter-relations of roots and shoots were confirmed.

A comparison has been made between the analyses of soil pore space atmosphere using the normal type sampling tube and Haldane gas analysis apparatus, and samples obtained by means of a hypodermic needle from a plastic-sided trench and analysed in a microgas analysis apparatus.

Soil tensiometers have been used during the growing season in the glasshouse in conjunction with the root growth observations and the type with compensating manometer is being used in a laboratory investigation of the rate of water movement through soil.

EXPERIMENTAL RESULTS OF 1952

I. TOMATOES

The practice of grading the tomato fruits from the experimental plots, adopted in 1921, was continued:—

A. "Pinks" number 5 to 7 and "Pink and White" 8 to 10 to the lb. These are the best quality of fruit in size, shape and colour; "Pinks" being slightly larger than "Pink and Whites."
B. "Whites." These fruits are of good colour but smaller than "Pink and Whites."
C. "Blues." This grade consists of fruits of good colour but larger and more irregular in shape than Grade A.
D. "Roughs." Small mis-shapen fruits about the size of cherries.
E. Blotchy fruits which ripen irregularly.
F. Fruits showing Blossom End Rot.
G. Fruits showing the lesions of Streak Diseases.
H. Fruits showing "Green Back."

(a) Planting Density

The number of plants planted out in an acre of glasshouses varies considerably from one part of the country to another. In the Lea Valley it is usually 16,000. In the Worthing area it varies from 14,000 to 16,000 and in Guernsey the number is often as low as 12,000 per acre.

Experiments conducted here in 1936 and 1937 indicated that there was little difference in crop yield when the density varied from 13,000 to 16,500 per acre, but that the crop yield was reduced when there were only 11,000 plants per acre.

In 1952 it was decided to pursue the enquiry still further by reducing the planting density to an absurdly low figure. In house 3, therefore, four plots were planted at a density of 16,000 plants per acre, which is standard practice at the Research Station, while four plots were planted at a density of 8,000 plants per acre. The variety was E.S.1 and the low density was obtained by omitting half the plants from each double row, so that the plants remaining were staggered in the rows.

The results are set out in Table I. Some will notice with surprise that the total crop yield is practically the same from the two densities, which means that the plants receiving twice the amount of space produced twice the weight of crop per plant. It will also be seen that the average percentage of good fruit estimated as Pinks, and Pink and Whites, is higher in the lower density, 77·06 per cent., than in the closer planting 64·73 per cent. Also there is slightly less blotchy fruit 0·40 per cent., than in the closer planting, 0·63 per cent.

Despite all this, however, there is an important adverse result, which can be seen in the first three months of picking and especially in May and June where the crop picked from the lower density plants is appreciably less than that from the closer planting. In June, for instance, the loss amounts to about 1 ton per acre. The total value of both crops calculated on the prices actually received by us from the market was £4,832 2*s.* 7*d.* per acre from the crop planted at normal spacing of 16,000 plants per acre, and £4,740 11*s.* 7*d.* per acre from the plots at half density, namely 8,000 plants per acre. This indicates a sum of £91 11*s.* 0*d.* in favour of normal planting. This takes no account of the very considerable saving in labour costs in attending to 8,000 instead of 16,000 plants. The investigation is obviously one of some importance and is being continued in 1953, when after planting at a density of 16,000 plants per acre, half the plants will be "stopped" at four trusses and be removed later.

(b) House 4. Deficiency Plots, Leather Waste and Seaweed

The deficiency plots 1 to 3 and 10 to 12 shew the same type of result as they have done for the last 30 years, the unmanured plot and the low potash plots both yielding a high proportion of blotchy fruit. The addition of leather waste to plots 4 and 9 has maintained a yield of 40 tons per acre. Milled dry seaweed—4 ozs. per sq. yd.— was incorporated in the top 8 ins. of plots 5 and 7, but there was no difference in yield when compared with the control plots 6 and 8. The variety was Delicious, and the results are given in Table II.

TABLE I

PLANTING DENSITY: VARIETY: E.S.1

House	Plot	Planting Density (Plants per Acre)	Crop Yield in Lbs. per Square Yard											Total Tons per Acre	Average Tons per Acre	% Blotchy Fruit	Average of Blotchy Ripening	% 'Pinks' and 'Pink and Whites'	Average % 'Pinks' and 'Pink & Whites'
			May	Average	June	Average	July	Average	Aug.	Average	Sept.	Average	Total	Average							
3	2	16,000	0·23		5·73		4·17		4·85		5·30		20·28		43·80			0·73		64·81	
	3	16,000	0·16		5·29		4·37		4·71		4·75		19·28		41·65			0·67		65·52	
	5	16,000	0·17	0·44	5·91	5·69	4·79	4·61	5·51	4·89	4·70	4·76	21·08	20·35	45·54	43·97		0·62	0·63	62·43	64·73
	8	16,000	1·09		5·82		5·09		4·50		4·27		20·77		44·87			0·48		66·15	
	1	8,000	0·69		5·14		4·95		4·39		5·11		20·28		43·80			0·40		75·15	
	4	8,000	0·18		5·19		4·79		6·10		5·84		22·10		47·74			0·27		75·97	
	6	8,000	0·21	0·36	4·93	5·16	4·01	4·48	5·39	5·17	5·09	5·22	19·63	20·38	42·40	44·03		0·71	0·40	78·13	77·06
	7	8,000	0·36		5·36		4·15		4·81		4·84		19·52		42·17			0·20		78·99	

TABLE II

DEFICIENCY PLOTS, LEATHER WASTE AND SEAWEED: VARIETY DELICIOUS

House	Plot	Treatment*	Crop Yield in Lbs. per Plant						Total Tons per Acre	% Blotchy Ripening
			May	June	July	Aug.	Sept.	Total		
4	1	C.A. without nitrogen	0·45	0·66	0·64	0·34	0·36	2·47	18·77	0·81
	2	Unmanured	0·23	0·47	0·47	0·34	0·34	1·85	14·06	8·12
	3	C.A.	0·24	1·81	1·45	1·26	1·38	6·14	46·66	0·97
	10	C.A. plus horse manure	0·23	1·66	1·30	1·29	0·89	5·37	40·81	2·05
	11	C.A. without phosphate	0·28	1·60	1·18	1·14	0·42	4·62	38·11	0·64
	12	,, ,, potash	0·35	0·44	1·20	0·64	0·29	2·92	22·19	15·08
	4	Leather waste	0·06	2·00	1·60	1·04	1·14	5·84	44·38	1·89
	9	,, ,, ...	0·21	1·92	1·33	0·94	0·93	5·33	40·51	0·94
	5	Milled seaweed: 4 ozs. per sq. yd.	0·04	1·53	1·44	1·31	1·12	5·44	41·34	1·84
	7	,, ,, ,, ,, ,, ,,	0·60	1·58	1·37	1·11	1·00	5·66	43·02	1·59
	6	Control for plots 5 and 7	0·01	1·56	1·57	1·33	1·00	5·47	41·57	1·46
	8	,, ,, ,, ,, ,, ...	0·15	1·58	1·42	1·06	0·86	5·07	38·52	1·77

* All plots except 5 and 6 treated with D.D. Plots 5 and 6 treated with chloropicrin

TABLE III

DRIP WATERING AND SULPHUR TREATMENT: VARIETY: POTENTIAL

House	Plot	Treatment	Crop Yield in Lbs. per Plant						Total Tons per Acre	% Blotchy Ripening
			May	June	July	Aug.	Sept.	Total		
5	1	Control for Plot 6	0·14	1·48	1·36	1·01	1·04	5·03	38·23	2·99
	6	Watered by Drip system	0·20	1·65	1·02	1·18	0·57	4·62	35·11	1·72
	2	Control for Plots 3 and 5	0·18	1·51	0·88	1·24	1·07	4·88	37·09	1·03
	4	,, ,, ,, ,, ,, ...	0·17	1·34	1·44	1·45	1·23	5·63	42·79	0·54
	3	Sulphur 1 lb./sq. yd.	0·14	0·98	1·02	1·15	0·99	4·28	32·52	0·23
	5	,, 8 ozs./sq. yd.	0·15	1·14	1·07	1·14	0·92	4·42	33·59	0·90

TABLE IV

STEAM STERILIZATION v. D.D.: VARIETY, E.S.5

House	Plot	Treatment	Crop Yield in Lbs. per Plant								Total Tons per Acre	Average Tons per Acre	% Blotchy Fruit
			May	June	July	Aug.	Sept.	Oct.	Nov.	Total			
8	1	Steam sterilization ...	0·19	1·93	1·12	1·52	1·71	0·43	0·16	7·06	53·66	50·41	0·42
	4	,, ,, ...	0·08	1·88	1·22	1·51	1·82	0·69	0·26	7·46	56·70		0·26
	6	,, ,, ...	—	1·40	1·09	1·21	1·61	0·53	0·26	6·10	46·36		0·16
	7	,, ,, ...	—	0·03	0·97	1·17	2·00	0·41	0·13	5·91	44·92		1·36
	2	D.D.	0·21	1·41	0·76	1·06	1·58	0·42	0·19	5·63	42·79	39·25	1·07
	3	,, ...	0·16	1·35	0·78	1·06	1·50	0·40	0·20	5·45	41·42		0·18
	5	,, ...	—	1·04	0·74	0·93	1·44	0·45	0·29	4·89	37·16		1·23
	8	,, ...	0·06	0·92	0·74	0·94	1·46	0·37	0·20	4·69	35·64		—

TABLE V

STEAM STERILIZATION, FORMALDEHYDE AND CHLOROPICRIN: VARIETY: AILSA CRAIG

House	Plot	Treatment	Crop Yield in Lbs. per Plant								Total Tons per Acre	Average Tons per Acre	% Blotchy Fruit
			May	June	July	Aug.	Sept.	Oct.	Nov.	Total			
9	1	Steam sterilization ...	0·08	1·43	0·94	1·01	0·97	1·13	0·21	5·77	43·85	44·87	—
	5	„ „ ...	0·02	0·97	0·96	0·99	0·87	1·43	0·21	5·45	41·42		0·18
	9	„ „ ...	—	1·00	1·19	1·23	1·40	1·30	0·40	6·52	49·55		—
	13	„ „ ...	—	1·14	1·30	1·07	0·85	1·32	0·21	5·89	44·76		0·17
	3	Formaldehyde ...	—	1·06	0·99	0·83	0·84	1·41	0·25	5·38	40·89	41·18	—
	6	„ ...	—	1·02	0·98	0·86	0·96	1·51	0·29	5·62	42·71		0·18
	10	„ ...	—	0·92	1·33	0·87	0·78	1·17	0·24	5·31	40·36		0·37
	15	„ ...	—	0·91	1·10	0·87	0·85	1·35	0·28	5·36	40·74		—
	4	Chloropicrin ...	0·04	0·92	1·11	1·53	0·86	1·32	0·28	6·06	46·06	49·57	—
	8	„ ...	—	1·49	1·79	1·19	1·43	1·62	0·49	8·01	60·88		—
	12	„ ...	—	0·93	1·11	1·09	1·11	1·52	0·22	5·98	45·45		—
	16	„ ...	0·02	1·12	1·23	1·14	0·87	1·42	0·24	6·04	45·90		0·16
	2	Control	0·01	1·40	1·07	0·85	0·64	1·54	0·28	5·79	44·00	41·06	0·18
	7	„	0·01	1·01	0·83	0·75	0·81	1·31	0·35	5·07	38·53		0·79
	11	„	—	0·85	1·10	0·81	0·81	1·10	0·27	4·94	37·54		0·18
	14	„	—	0·93	1·30	0·80	1·11	1·47	0·20	5·81	44·16		0·18

TABLE VI

SOIL STEAM STERILIZED: VARIETIES: PLOTS 1 AND 4, E.S.1; PLOTS 2 AND 3 POTENTATE

House	Plot	Treatment	Crop Yield in Lbs. per Plant							Total Tons per Acre	Average Tons per Acre	% Blotchy Fruit	Variety
			June	July	Aug.	Sept.	Oct.	Nov.	Total				
11	1	Standard	0·89	2·51	1·91	1·45	0·73	0·38	7·87	59·81	65·51	1·14	E.S.1
	2	„	0·65	2·89	1·99	1·19	0·66	2·14	9·38	71·29		5·76	Potentate
	3	No lime	0·43	3·27	2·41	1·15	0·62	1·75	9·63	73·19	68·60	10·80	„
	4	„ „	0·63	3·62	1·77	1·51	0·55	0·47	8·55	64·98		4·91	E.S.1
12	1	No phosphates ...	0·93	2·11	1·60	1·41	0·01	0·56	7·64	58·06	64·79	3·01	„
	2	„ „ ...	1·43	2·70	2·26	0·79	0·51	1·72	9·41	71·52		12·13	Potentate
	3	No phosphates and no lime	1·58	2·85	2·21	1·55	0·37	1·18	8·19	62·24	57·68	11·36	„
	4	Ditto	1·61	2·34	1·75	1·29	0·39	0·90	6·99	53·12		3·01	E.S.1

(c) Drip Watering

The drip watering system was tested for the third year in house 5, plot 6; the control, watered by hand being plot 1. The control plot showed a slightly higher total yield but the drip system gave a slightly higher yield in May and June. See Table III.

(d) The Addition of Sulphur to the Soil

This year marks the end of this experiment which was started in 1943 to determine if under our conditions the lowering of the soil pH by the addition of flowers of sulphur would alter the habit of the tomato plant, increase its resistance to diseases and pests and increase the total yield of fruit.

Four plots in house 5 were set apart for the experiment, lime being withheld from any further fertilizer treatment. Two plots were given sulphur at the rate of 2 ozs. and 4 ozs. respectively, another received sulphuric acid equivalent to 2 ozs. sulphur per sq. yd. while the fourth was left as a control.

From 1943 to 1950, there was no difference either in crop weight or quality of the fruit from treated and untreated plots. Neither was any difference observed in susceptibility to attack by *Cladosporium fulvum*, *Botrytis cinerea*, or any of the virus diseases.

In 1951, growth was retarded for some weeks in the plot receiving 1 lb. of sulphur per sq. yd., but it recovered later and total yield equalled that of the controls.

In 1952, however, about one-third of the plants in this plot collapsed suddenly about the beginning of May. Examination showed the roots and base of the stem to be completely rotten and invaded by various species of *Penicillium*. No signs of any active parasite were observed and it was concluded that the roots had been destroyed by chemical means.

Examination of the soil around the roots showed considerable variation in pH value from place to place, the average value being about 3·40. In June the pH had fallen to 3·00; in July it was 4·18 and in August 3·32. Sixty-one plants out of 120 survived throughout the season and carried a reasonable crop. It seemed that in such cases the roots had penetrated deeply into a more alkaline layer of soil.

This experiment was started in 1943 because it was considered by some that a high soil pH was detrimental to the tomato crop and we were curious to know if any improvement in our crops could be obtained by reducing the pH. So far as our conditions are concerned the results have been negative, for speaking generally we have observed no differences either in crop yield or quality of fruit when the pH has been reduced by the sulphur method.

The chemical implications, however, will be dealt with in the report of the Chemistry Department.

(e) Steam Sterilization v. "D.D."

The soil sterilization trials in house 8 were continued, four plots being sterilized by steam and four by the injection of "D.D." Both proved effective against the tomato root knot eelworm, but the crop yields showed a considerable difference. The average from the four steamed plots was 50·41 tons per acre, but from the "D.D." plots it was only 39·25 tons per acre.

The results are given in Table IV.

(f) Steam Sterilization v. Formaldehyde and Chloropicrin

House 9 was divided into four blocks of four plots each, the three treatments and a control plot, being randomised in each block.

The results indicated in Table V show that the yield from both steam sterilization and chloropicrin was higher than the control, whereas the formaldehyde treatment was ineffective. If one unusually high yield in the chloropicrin plot is omitted then the result of treating the soil with this substance is equal to that of steaming and this confirms previous results.

The relatively small increase in yield following soil sterilization is an unusual feature of these results and the failure of formaldehyde is surprising. It should be noted, however, that owing to poor light during the first six weeks after planting the whole of the plants in this block of houses became very soft and could only be strengthened by a drastic lowering of the night temperature. It is possible that under these conditions the plants could not take full advantage of the sterilized soil.

TABLE VII

Variety Trials

House	Plot	Variety	Crop Yield in Lbs. per Plant							Total Tons per Acre	% Blotchy Ripening
			May	June	July	Aug.	Sept.	Oct.	Total		
Rose House	1	Potential	0·04	0·84	3·42	1·29	0·46	0·96	7·01	53·28	3·56
	2	Wheatleys	0·01	1·97	2·50	1·07	0·58	1·08	7·21	54·79	11·79
	3	Scarlet Knight ...	—	1·55	3·00	1·01	0·47	0·79	6·82	51·83	8·21
	4	Scarlet Emperor ...	—	1·71	2·85	1·20	0·55	1·04	7·35	55·86	6·53
	5	Melville Castle ...	—	1·91	2·45	0·88	0·47	0·89	6·60	50·16	3·03
	6	Downes Seedling ...	0·01	1·91	2·64	1·27	0·54	0·89	7·26	55·18	11·57
	7	Dufferns Seedling ...	0·02	2·23	2·11	0·94	0·49	1·34	7·13	54·19	4·64
	8	Delicious	0·06	0·90	3·29	0·92	0·63	1·54	7·34	55·78	5·46
	9	Aldourie	—	1·42	1·99	2·03	1·00	2·07	8·51	64·68	4·12
	10	Carlton	—	2·40	1·25	0·50	0·76	1·70	6·61	50·24	5·15

TABLE VIII

Cucumbers: Butchers Disease Resister. Soil Steam Sterilized

Plot	Treatment	Crop Yield in Lbs. per Plant								Total Tons per Acre	Average Tons per Acre	Total Flats per Foot
		Mar.	Apr.	May	June	July	Aug.	Sept.	Total			
D2	Beds: Steamed soil with manure and complete fertilisers ...	1·28	11·36	10·05	8·81	8·73	8·80	5·26	54·29	81·43		1·70
E3	Ditto	0·76	9·28	10·43	7·15	9·23	6·24	1·79	44·88	67·32	73·81	1·40
F4	Ditto	0·66	9·78	10·62	8·46	7·23	6·79	2·91	46·45	69·67		1·45
G5	Ditto	0·64	10·49	11·93	8·07	9·89	7·45	2·75	51·22	76·83		1·60
E5	Beds: Steamed soil with manure and bone meal only ...	0·90	9·45	10·48	6·53	8·27	7·02	2·46	45·11	67·67		1·41
F5	Ditto	0·77	10·50	11·29	7·26	8·17	7·16	3·75	48·90	73·35	73·40	1·53
G3	Ditto	0·91	10·49	9·36	8·00	10·45	8·77	4·81	52·79	79·18		1·65
D3	Beds: Virgin soil with manure and complete fertilizers ...	0·99	11·15	9·91	7·40	8·32	7·46	5·00	50·17	75·25		1·57
E2	Ditto	1·22	8·82	10·27	6·96	8·54	8·59	2·56	46·96	70·44	74·68	1·47
F3	Ditto	0·76	8·93	9·89	9·61	9·41	7·76	3·23	49·59	74·38		1·55
G4	Ditto	1·01	11·15	10·87	8·43	10·30	7·71	2·93	52·42	78·63		1·64
E4	Beds: Virgin soil with manure and bone meal only ...	0·75	11·29	10·16	7·41	8·84	5·59	1·97	46·01	69·02		1·44
F2	Ditto	0·91	9·57	8·43	7·26	8·60	7·36	2·50	44·63	66·94	72·45	1·40
G2	Ditto	0·32	11·66	11·06	9·44	10·77	7·33	3·68	54·26	81·39		1·70
D5	Drip watering	1·96	12·70	11·90	8·48	8·16	8·09	5·58	56·87	85·30		1·78

(g) The Omission of Lime and Phosphates

The experiments in houses 11 and 12, started in 1947 were continued. The results are given in Table VI. The omission of lime and also phosphates alone for six years has not affected the yield, but there was some reduction where both lime and phosphates were withheld.

(h) Variety Trials

The variety trials were continued in the Rose House; the results are given in Table VII. The variety Aldourie gave the highest yield; otherwise there were no outstanding results.

2. CUCUMBERS

In the cucumber experiments the soil in the houses was steam sterilized and then injected with "D.D." to destroy any root knot eelworms that remained alive after the steaming. The treatment proved effective when judged by the absence of nodules on the roots at the end of the season, but bees again proved troublesome and caused some reduction in yield.

In the cucumber experiments an attempt was made to see if any difference could be obtained by making up the beds with virgin soil unsteamed as against the same virgin soil steamed. Further, it has been standard practice at the Research Station for many years to apply only bone meal to the beds as a first top-dressing as soon as the young plants have established themselves. This year an attempt was made to see if any improvement resulted from the use of a complete fertilizer instead of only bone meal at this stage.

Thus there were four plots of steamed soil and horse manure with complete fertilizers as a first top-dressing and also four plots with bone meal only. In comparison with these there were four plots of unsteamed virgin soil and horse manure with complete fertilizers as a first top-dressing and four plots with bone meal only. The results given in Table VIII do not show any real differences between the yields from the various treatments and it can be concluded that steam-sterilized virgin soil is as good as the unsteamed soil: also that a first top-dressing of bone meal is adequate and no increase in crop is produced by adding other nutrients at this stage.

Once again the plot watered by the drip system has given the highest yield of all.

3. CARNATIONS

The carnation experiments which ended in February, 1952, were a repetition of the previous series. One bed was made up over a solid brick base, another over a base of 2-in. drain tiles packed closely together, while a third bed was placed directly on the floor of the house and used as a control. The fourth bed was made in a concrete trough raised above ground level. In half of the trough the drainage was good: in the other it was poor and the soil at the bottom never dried out.

The number of flowers per plant from four varieties picked from the different beds during a period of 14 months are given in Table IX.

TABLE IX

CARNATIONS. YIELD IN FLOWERS PER PLANT FROM NOVEMBER, 1950 TO DECEMBER, 1951

Variety	Beds over Brick Base	Beds over Drain-tile Base	Beds in Trough		Control Beds in Direct Contact with Soil Below
			Well Drained	Badly Drained	
Ashington Pink ...	16·51	18·60	21·27	18·02	16·29
White Maytime ...	18·51	18·90	22·63	20·69	17·11
Maytime	17·22	17·33	22·38	18·13	16·79
William Sim ...	15·94	17·52	20·25	15·50	15·45
Average	17·05	18·09	21·63	18·09	16·41

The number of flowers per plant vary according to variety, White Maytime being on top in every case.

Some slight advantage was shown in the beds on bricks and tiles over the control, but the highest yield came from the well-drained half of the trough.

II. PLANT DISEASES

1. DIDYMELLA STEM ROT

By JUDITH HACK and P. H. WILLIAMS

Differences in Growth of Various Strains of Didymella lycopersici in Soil

Work at Cheshunt during the past few years has shown (Annual Report 1949, 1950) that great differences in the ability of *Didymella lycopersici* to grow in sterilized soil result from differing temperature, moisture, and nutritional conditions. Using the same technique employed for that work, namely that of inoculating soil in conical flasks with a spore suspension of *D. lycopersici* and plating it out after a period of incubation, it has been learned this year that different strains of *D. lycopersici* vary greatly in their ability to increase under the same soil conditions. Furthermore, it has been found that such differences in strains are revealed fully only when tests are made with several soils.

That strains of *D. lycopersici* vary in their ability to increase in soil would be anticipated from work with cultures of the fungus on synthetic media. Initially work with this fungus was hampered because of difficulty in obtaining sporulation on artificial media (Annual Report 1948). Recently, however, strains have arisen from poorly sporing stocks which produce large numbers of pycnidia and spores within a fortnight's incubation on Czapek-Dox agar.

McLennan[1] has shown that the vegetative build-up of fungus mycelium in sterilized soil is not accompanied by an increase in numbers obtained on plating, but that sudden inceases occur coincidental with sporulation. From this one may infer that the apparent failure of *D. lycopersici* to increase in numbers on plating from soil means a failure to sporulate, and one would look to presence or absence of such increases in strains showing presence or absence of sporulation on synthetic media.

Spores of four strains of *D. lycopersici* have been examined by a direct method for behaviour when inoculated into moist, sterilized soil. In the case of all strains the great majority of spores germinated and developed a mycelium which spread throughout the body of the soil under observation. In these tests development on two soils from the station glasshouses was compared with development on maiden loam, but no differences in vegetative growth due to soil or strain were observed.

Behaviour as regards sporulation in soil was in contrast to the uniformity shown by different strains in vegetative development. A known number of spores of four strains of *D. lycopersici* were inoculated into moist, sterilized maiden loam in flasks. All strains tested so far have shown considerable increases in numbers on plating after one month's incubation, though there is as much as a fifty-fold difference between extremes. When the same strains were grown in soil from the station glasshouses, the increase in the case of two of them was considerable, though less than on maiden loam, while the other two showed no increase.

The relation of sporulation of different strains to soil and to artificial media is complex. This is shown by the fact that while strains which spore freely on Czapek-Dox agar will also do so on maiden loam, they do not necessarily spore freely on nursery soils.

Development of Didymella lycopersici in Glasshouse Soil after Steaming

From the work described above it is clear that with the right strains of *D. lycopersici*, the infection potential produced by the growth and sporulation of *Didymella* spores alighting on freshly-steamed glasshouse soils may be very great, but on unsteamed soil *Didymella* spores are known to die out (Read, Annual Report, 1946). After steaming there is presumably a gradual return from a near sterile condition to the microbial population typical of unsteamed soil. A field experiment was carried out this year to determine how long after steaming the soil must be considered a dangerously favourable medium for the development of *D. lycopersici*.

Soil in a glasshouse was steamed in November, 1951, by the Hoddesdon pipe method and immediately shovelled into 10-in. pots. These were sunk in the ground in the position normally occupied by tomato plants in order to minimise drying out. A day after steaming and at intervals thereafter over a period of three months sets of pots were inoculated with a known quantity of

D. lycopersici spores of a strain capable of sporulating in this soil. Flooding was carried out two weeks after steaming. The pots were lifted in March, placed on the soil surface and immediately planted with tomatoes variety Potentate, further sets being inoculated just before and just after planting. In the latter case the entire spore suspension was poured over the base of the plant.

During the growing season the plants were examined frequently for the presence of lesions. It was found that while the first plants to show lesions were recorded four weeks after planting, others had only just developed Stem Rot 32 weeks later. The earliness with which each set of plants showed the disease as well as the percentage infection was, therefore, considered a very important criterion of the severity of the disease and, hence, of the infection potential that had been built up.

Taking the degree of disease in the set of plants where the soil was inoculated immediately before planting as a reference, it was plain that *D. lycopersici* had increased greatly in the soil of sets where inoculation took place immediately or shortly after steaming and to a lesser extent where inoculation was somewhat later. There was in general a decline in the severity of the disease in sets inoculated further and further from the time of steaming, and the set last inoculated was slightly, though not significantly less severely affected than the reference. As would be expected, most disease was shown by that set of plants over which the whole inoculum had been poured after planting.

The results of this experiment support the idea that very severe attacks of *Didymella lycopersici* may be related to infection of soil soon after steaming. Although in the period between steaming and planting steamed soil does not appear to acquire the ability to kill off *D. lycopersici* possessed by unsteamed soil, this experiment shows that it has by that time gradually become a medium less favourable for multiplication of *D. lycopersici.*

Microbial Antagonism in the Soil

During the past 10 years only scattered cases of Stem Rot have been seen on the Station nursery. The failure of *D. lycopersici* to establish itself may possibly be due to the presence in the soil of large numbers of other organisms antagonistic to it.

Accordingly, a number of organisms were isolated from soil from house 11 and from a house on a commercial nursery in which Stem Rot had been severe. These organisms were tested for antagonism by growing them with two strains of *D. lycopersici* on plates of Dox agar. The production of an antibiotic substance by the test organism was shown by cessation of growth of *D. lycopersici* as the two colonies grew towards one another.

Of the organisms tested, 30 per cent. of those from the Station soil and 28 per cent. of those from the commercial nursery proved able to stop the growth of *D. lycopersici.* It would appear from this result that the failure of *D. lycopersici* to spread in the Station soil is not due to antagonism by the organisms we isolated. It is possible that the strains of *D. lycopersici* introduced by aerial infection were not capable of sporulating on this soil and therefore of building up a high infection potential.

Inoculation Experiments

Cultures of *D. lycopersici* were obtained from Mr. W. Campbell, N.A.A.S., who isolated them from strawberry plants and from tomato fruit growing in adjoining fields in Devon. The cultures were compared with cultures from tomato fruit taken from glasshouses in which typical Stem Rot was present.

The glasshouse cultures were darker and produced less aerial mycelium than those from strawberry and outdoor tomato fruit. When inoculated into green tomatoes, a black rot with pycnidia was produced by all cultures. The glasshouse strains produced typical lesions on tomato stems when a piece of culture was placed on a wound made by removing a leaf. With the strawberry and outdoor tomato strains only pale superficial lesions were formed and no pycnidia were seen. Further experiments are planned.

Rate of Penetration of Wounds

Treatment of wounds made in trimming has been suggested as a means of preventing infection. It could, however, happen that the wound would be infected by spores before the treatment could be applied and in such a case, the fungus might penetrate beyond the reach of the fungicide. A preliminary experiment has been carried out to determine the rate of growth of the fungus in tomato tissue.

Leaves were cut from plants growing in 6-in. pots leaving a stub of petiole about 1 cm. long. A spore suspension was applied to the cut ends. Stubs were removed at intervals, sections cut from them and the depth of penetration measured. After 24 hours, the fungus appeared to be confined to the tissue immediately inside the wound. In 48 hours it had penetrated 1·0–1·5 mm. After 120 hours it did not appear to have made much more progress, but the tissues were turning brown. Two days later the remaining stubs had shrivelled up. The plants with the shrivelled stubs were kept and subsequently developed lesions on the stems at the inoculated nodes, the fungus having grown through 1 cm. of petiole in seven days.

Length of Time Wounds remain Susceptible to Infection

The third, fifth, and seventh leaves were removed from a batch of 50 tomatoes variety Potentate. From half the plants they were cut off cleanly with a sharp knife and from the remainder they were snapped off, leaving a certain amount of broken tissue round the wound. The first leaves were removed from 10 plants (from five by each method) at 5 p.m. on one day and the remainder at intervals during the next, all the wounds being inoculated at 5 p.m. on the second day. Wounds were therefore allowed to dry for 24, 9, 7, 2, and 0 hours before inoculation. Temperature and humidity conditions were such as to favour drying of the wounds.

A final examination of the plants was made five weeks after inoculation. The results showed that the time that elapsed before inoculation was not significant but that more wounds became infected where the third and fifth leaves had been removed and where the leaves had been snapped off instead of being cut off.

Owing to limitations of space it was impossible to arrange the plants in randomised blocks, but the various treatments were mixed as well as possible. When the final examination was made, there appeared to be fewer lesions on plants at the end of the chamber nearest the door irrespective of treatment. The above results should therefore be treated with reserve until confirmed by further experiments. It would appear that *D. lycopersici* may be more sensitive to small variations in atmospheric conditions than has been thought hitherto.

REFERENCE

' McLennan, E., 1928. The Growth of Fungi in Soil. Ann. Appl. Biol. **15**, 95–109.

2. TOMATO ROOT ROT

By M. H. EBBEN and P. H. WILLIAMS

Isolations of Fungi from Root Debris

Root debris in the soil may serve as a reservoir for fungi pathogenic to tomato roots. Accordingly samples have been removed at intervals from two plots.

These plots were cropped in 1951 when rhizosphere studies were carried out on the plant roots. One plot had been steamed in the autumn of 1950 and the other in the autumn of 1949. Root debris was removed for examination at intervals during the first two months of 1952. Isolations were made by diluting and plating the suspension obtained when the root debris was shaken in sterile water, and from the dead roots themselves. These were removed from the suspension dried, flamed quickly and placed on agar-plates. Dead roots were removed from the soil at depths of 3 to 6 ins. and 6 to 9 ins.

Several series of isolations were made, but there was so little infection of the dead roots from the lower-soil level that this was discontinued. There was wide variation in the percentage of dead roots infected, but isolations from roots from unsteamed soil were made from 55 to 100 per cent. of those plated, while from the steamed soil the range was from 12 to 66 per cent.

Most of the fungi found in the soil were also isolated from the root surface and from the actual dead root tissue. Species of *Penicillium* were frequent from all three sources, *Mucor* spp. were less common on the root surface and tissue than in the soil, *Fusarium* spp. were isolated from all three sources and although numbers were variable were occasionally very common from the root tissue. The grey sterile fungus K and *Myrothecium roridum* were isolated more often from the soil than from dead roots. The root pathogen *Colletotrichum atramentarium* was only occasionally isolated from the root surface and root tissue and then only from dead roots from unsteamed soil.

When the dead roots were air dried before being placed on agar plates only *Penicillium* spp., K and *C. atramentarium* were isolated. *Fusarium* spp. and *Myrothecium roridium* were not found.

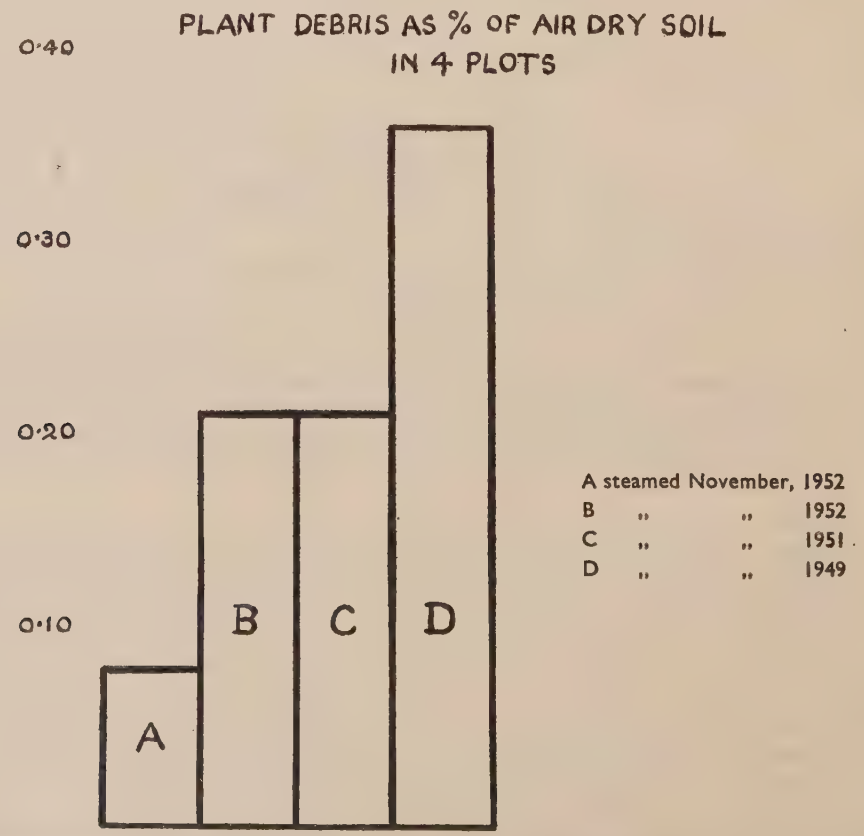
Sterilized dead roots were buried in jars of unsterilized soil from the steamed and unsteamed plots, and incubated for one month. The root debris was then removed, surface sterilized and plated. Little fungal and bacterial growth developed from any of the roots. It seems probable that reinfection of dead roots after sterilization is slight, and possibly infection of clean dead roots left on the soil may also be slow, although numbers of soil fungi are considerable. The root debris which persists in the soil consists almost entirely of pieces of the central cylinder, the cortical tissues usually having disappeared entirely. Although fungi previously present in the living roots might survive it does not seem likely that other fungi would invade this habitat.

Undecomposed Plant Debris in Glasshouse Soil

It has often been noticed when taking soil samples that soil from unsteamed plots appeared to contain more dead root debris than the steamed soil plots. A method was used to compare the amount of undecomposed organic matter in the soil, in which the plant material was centrifuged out of a water suspension of a known weight of air dry soil, collected on a 0·4 millimetre sieve, dried and weighed.

Soil tested was collected from plots all in the same glasshouse which had been steamed at different times and cropped continuously.

Although there was an accumulation of undecomposed debris in soil left unsteamed for three seasons, results from other plots were variable. (See Fig. 1.) It was also found that in the two plots steamed one month before sampling (A and B) numbers of bacteria in the soil were very different although the level of the fungal population was similar. These plots had been steamed at the same time and previously received the same fertilizer treatment but whereas plot B was in the middle of the border and plants had been grown on either side, plot A had a fallow plot on either side and the resulting difference in light conditions may have given rise to different root growth. Plot C, which was steamed in 1951, is comparable to Plot A, steamed 1952, as both had fallow plots on either side and light conditions for the plants would be better than normal.



The numbers of fungi and bacteria in the soil of the different plots is shown in Table I.

TABLE I

NUMBERS OF ORGANISMS PER GRAMME OF DRY SOIL IN SOILS STEAMED AT DIFFERENT DATES.

Plots	A	B	C	D
Fungi	2,324	2,292	66,090	232,000
Bacteria	$0{\cdot}77 \times 10^6$	$3{\cdot}1 \times 10^6$	$28{\cdot}3 \times 10^6$	167×10^6
Date steamed ...	1952	1952	1951	1949

Rhizosphere Studies on Pot Plants

Sterilised soil in pots was planted with young tomato plants and inoculated with old tomato roots which had been artificially infected with some of the fungi found in tomato root rot investigations. Analysis of the fungal microflora of the soil and rhizosphere at intervals of two and five months indicates that:—

(1) *Colletotrichum atramentarium* established itself on the root surface and in the root itself but rarely in the soil.

(2) *Chætomium cochliodes* became established in the soil, on the root surface and in root tissue. It was also isolated from the stem.

(3) *Myrothecium roridum* was common in the soil and after five months had established itself on the root surface, but it did not appear to penetrate the roots.

(4) The sterile fungus K established itself in the soil and to a small extent on the root surface, but was rarely isolated from root tissue.

(5) After five months roots in all series showed a gradation in the numbers of fungi isolated from different zones of the root surface, thus distal zone > median zone > tap root zone, when numbers were calculated in relation to grammes of fresh root. This gradation may be due to the difference in surface area of roots of different bulk, especially as when the young root systems were sampled there was less differentiation in root bulk between the three zones and there was no clear indication of any gradation.

(6) In most cases the number of fungi isolated from a particular root zone increased from two to five months. Increase in soil fungi over the same period did not occur so commonly and was less marked.

3. BLACK STEM ROT OF CUCUMBERS

By P. H. WILLIAMS

During August, 1952, some cucumber shoots which were dying back were found in the houses at the Station. They were black in colour and examination showed the presence of numbers of pycnidia embedded in the tissue. On pieces of stem in a moist chamber, perithecia were formed. The shape and size of the ascospores showed that the fungus was *Mycosphærella citrullina*, the cause of a similar disease of melons and other cucurbits in the United States of America.

The fungus appeared to attack dead or dying tissues such as sideshoots which had been stopped or the stumps of leaf stalks and shoots at the nodes. Observation of selected plants over a four-week period showed that there was great variation in the progress of the disease. On some plants, it remained confined to the dead tissue at the nodes while on others the main stem was rapidly invaded and long lengths were killed. It may be suggested that the health of individual plants influenced the progress of the fungus which was unable to invade healthy tissue on the more vigorous plants.

A count of the total number of infected plants was made on September 3rd. Only the main stem and principal laterals were examined because of the difficulty of tracing other infected shoots back to their origin. The disease was worst in houses E and F and the plots in the middle and at the north end of houses D to F tended to be more severely affected than those at the south end. Infection in house G, which is separated from the older block by a wall, was relatively slight.

Inoculation Experiments

Some small scale inoculation experiments were carried out using freshly isolated cultures and one isolated from melon in 1947. In inoculating stems, leaves were removed and pieces of culture applied to the wound which was then covered with lead foil. The fungus was inserted under flaps of skin on vegetable marrow petioles and tomato fruit.

These experiments showed that cucumber and melon stems and marrow petioles could be attacked and that the fungus fruited on the diseased tissue. The fungus did not grow back into the stem from the infected petioles of vegetable marrows, nor were direct inoculations successful. Tomato stems were not invaded but there was slight rotting of tomato fruit.

Discussion

It is too early to say whether Black Rot is likely to be a serious disease of cucumbers. So far it has only been reported once before on cucumbers and once on melons, both in 1947. In both cases the disease occurred in July. This year it appeared late in the growing season at the Station and Mr. J. E. E. Jenkins, N.A.A.S., has informed us that he found it about the same time on a commercial nursery. It has been stated that susceptibility of cucumbers to the fungus increases with the age of the plant. It seems possible therefore that Black Rot may be confined to older plants which have been weakened by bearing a crop.

Where it appears, destruction of infected haulm, spraying the houses with formaldehyde and sterilizing the soil should be undertaken. By these means, chances of the fungus surviving until the next year should be eliminated.

4. VIRUS DISEASES

By R. HOWLES

This year's work has been the continuation of our efforts to destroy virus within infected plants and of research on chrysanthemum mosaic.

(a) Therapy

Heat

(1) Tomato Seed

Results reported in last year's Annual Report[1] indicated that exposure of tobacco mosaic virus infected tomato seed to normal atmosphere at 142·5° F. for 22 days reduced the virus content to less than 10 per cent. This year we sought confirmation of this reduction. Completely separated infected seed was well mixed and half was treated in this way. The virus content of the treated and of the control seed were compared by the half leaf method. The former was calculated to be about 7 per cent. of the latter (Table I). The treatment had little effect on the seed itself. This is shown in the table.

TABLE I

Effect on Lesion Count, Virus Content, and Seed itself of treating Tobacco Mosaic Virus infected Tomato Seed in Normal Atmosphere at 142·5° F. for 22 Days

	Experiment			% Virus Inactivated
	1	2	3	
Number of Lesions:				
Treated seed	31	34	106	7
Control „	94	159	195	–

	No. of Seeds which had Germinated out of 45, 17 Days after Sowing	Appearance of Seedlings	Average Weight of Seedling
Treated seed	44	Normal	0·125 gm.
Control „	42		0·106 gm.

One hundred plants from treated seed and 100 from control seed were grown on, but five months after sowing there were no infected plants. The explanation may be that the seed was too old.

(2) Chrysanthemum Stools and Rooted Cuttings

Chrysanthemum stools were given hot water treatment at the beginning of January. Potted cuttings were heat-treated standing in a tray of water. Cuttings from which the soil had been removed were heat-treated on moist blotting paper in an oven containing a tray of water. When a

month or over had elapsed after treatment the plants were tested for virus. Table II shows the treatments applied in each case, the effect on the plant itself and the result of tests. Virus was present in all treated plants.

TABLE II

Effect of Heat-treating Mosaic-infected Chrysanthemum Stools and Cuttings on the Plant Itself and on the Infection

Number and Nature of Plants	Treatment		Duration	Effect on the Plant Itself	Result of Testing for Virus one Month or longer later
	Heating Environment	Temperature (° F.)			
12 stools	Water	109·5	2½ hours	6 stools survived	Virus present
12 ,, ...	,,	109·5	5 ,,	0 ,, ,,	
12 ,, ...	,,	109·5	10 ,,	0 ,, ,,	
12 ,, ...	,,	109·5	20 ,,	0 ,, ,,	
11 ,, ...	,,	109·5	40 ,,	0 ,, ,,	
15 potted cuttings ...	Moist air	97·0	36 ,,	Cuttings just survived	Virus present
15 cuttings, soil removed from roots	,, ,,	97·0	24 ,,	Cuttings survived	,, ,,
Ditto	,, ,,	97·0	3 days	,, ,,	,, ,,
Ditto	,, ,,	97·0	9 ,,	All plants died	
Ditto	,, ,,	97·0	6 ,,	,, ,, ,,	

(3) Arum Lily Corms

Further heat treatments of Arum Lily corms were carried out. The previous work is described in our 1950 Annual Report.

Three groups of large arum lily corms, 18 in each group, were given hot water treatments at 109° F., the duration being respectively 20, 40, and 80 hours. There were 27 controls. Heat treatment and planting of corms occurred at the end of June. On October 29th, 1952, when there was no more likelihood of any more corms growing, the number which had produced plants was 17, 7, and 0 in the case of the treated groups respectively and 25 in the control group. The number of plants in each group showing symptoms of infection was respectively 10, 6, 0, and 11.

Two hundred and twenty-five small corms were mixed for 30 minutes. The corms were divided into 15 groups, 10 corms in each, for treatment and 75 controls. Five groups received hot water treatment at 93° F., another five moist air treatment at 107·5° F., and five more normal air treatment at the same temperature. In each case the durations in hours were 7, 16, 36, 81, and 182. Heat treatment and planting occurred at the end of June.

Fig. 1 illustrates the relation between number of corms which were growing out of 10, and duration of heat treatment in the case of each kind of treatment. More corms which received shorter hot water treatments and slightly more corms which received shorter moist air treatments sprouted than untreated corms. This agrees with the previous results. The longer the normal air treatment the fewer the corms which grew.

The relation between number of plants showing symptoms of infection divided by the number of corms growing and duration of heat treatment in the case of each of the three kinds of treatment is given in Fig. 2. In the case of the hot water and hot moist air treatments as duration of treatment increased the percentage infected plants rose, fell, then rose, this being in accordance with the previous data. In the case of the third kind of treatment the percentage infected plants rose then fell to zero. The best treatment appears to be normal air treatment of duration 58·5 hours, percentage infected plants being 25.

(4) Effect of Heat-treating Virus-infected Seeds on Weight of Seedlings

The heat-treatment work carried out here has shown that seedlings from virus-infected seeds heat-treated in normal atmosphere, in the case of certain treatments are heavier, than seedlings from untreated seeds.[1] We decided to carry out further work on this result.

Six 3 gm. lots were weighed out of 27 gm. of completely separated thoroughly mixed clean tomato (Potentate) seeds freed from small seeds. Each lot was heat-treated, and both treated seeds and control seeds were sown. The various heat treatments, ability of the seeds to germinate and average weight of seedlings are given in Table III. This time seedling weight of treated seeds was not greater than that in the case of the control seeds.

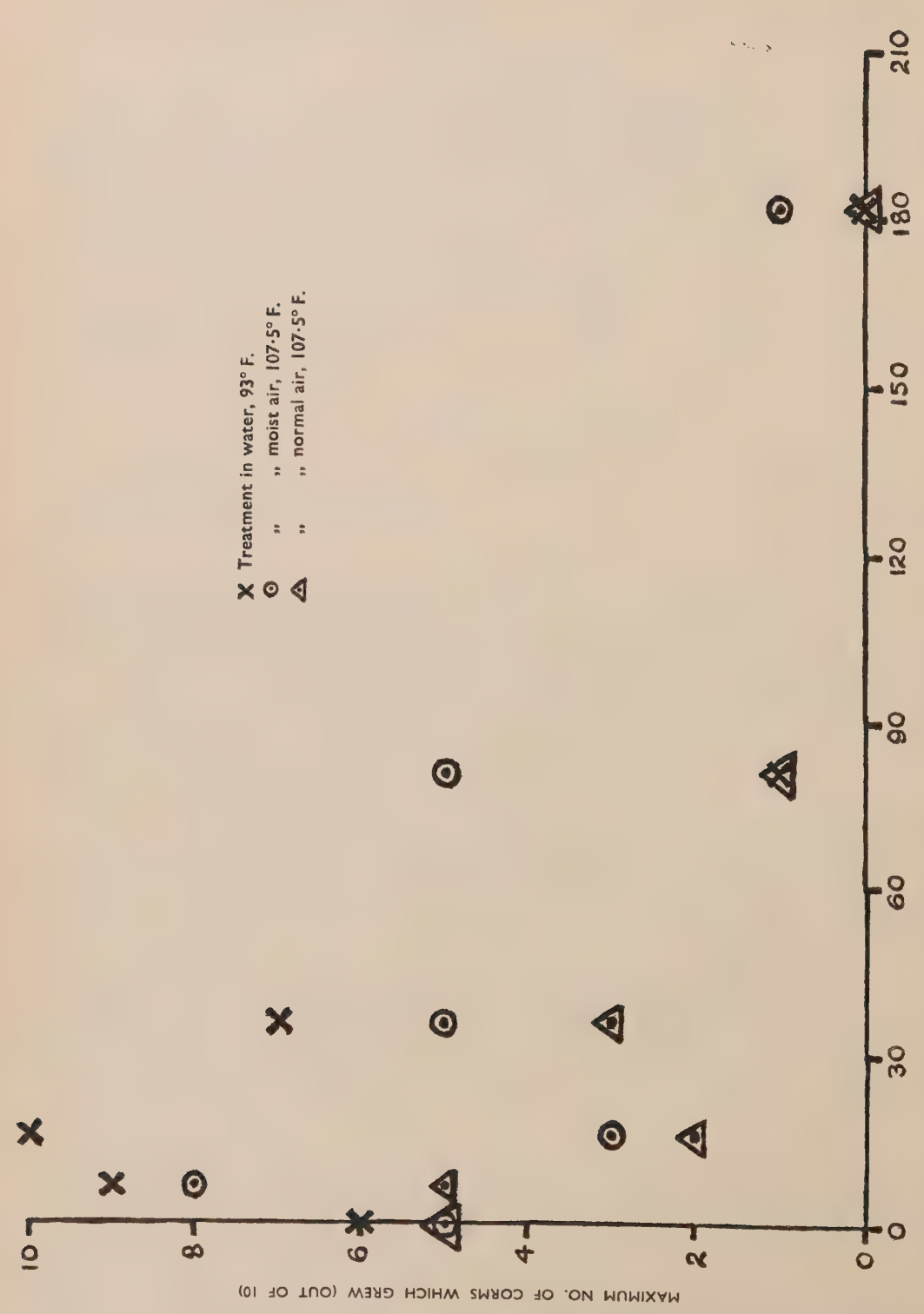


FIG. 1

Effect of duration of heat treatment on percentage "germination" of spotted wilt virus infected Arum Lily corms.

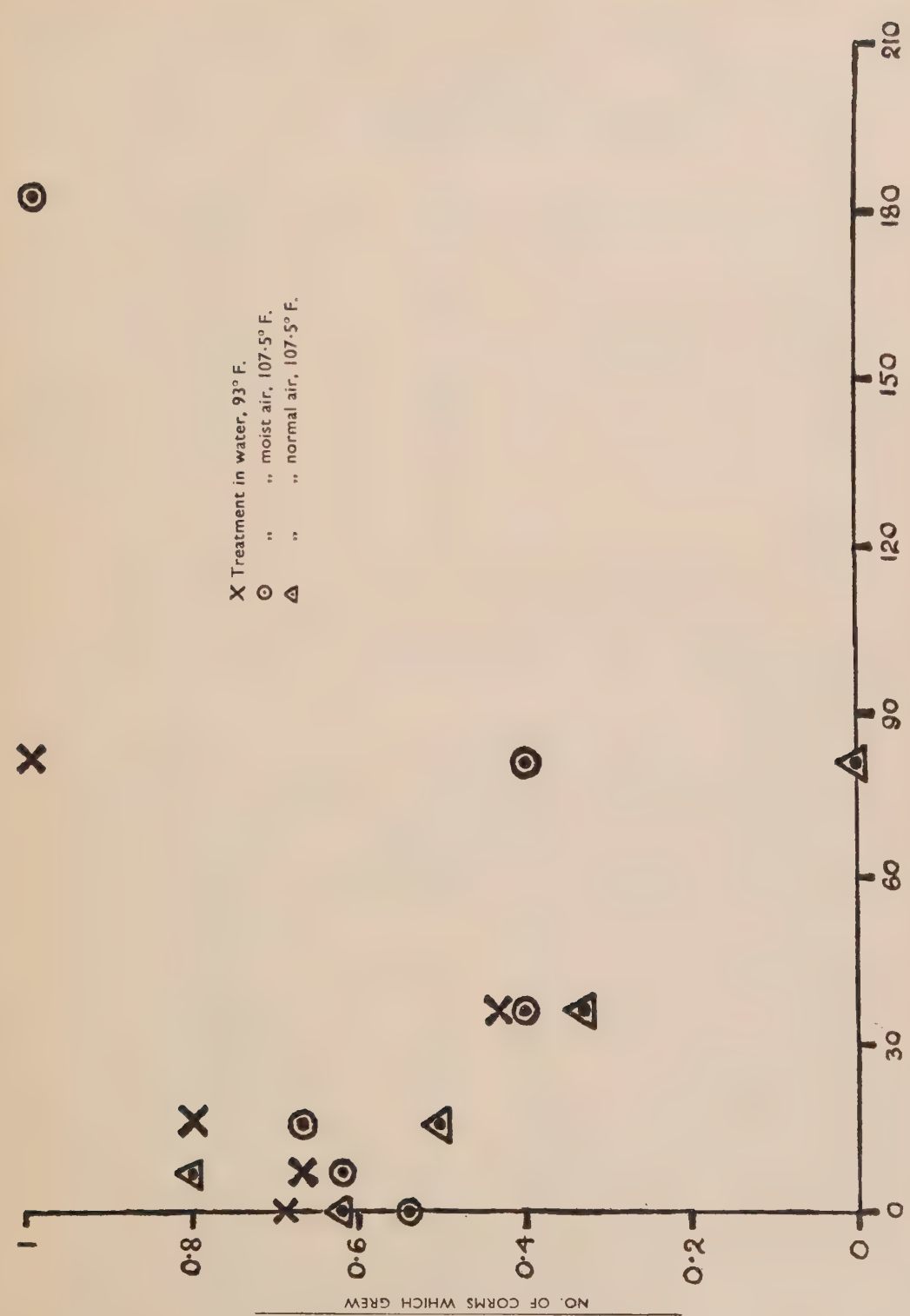


FIG. 2

Effect of duration of heat treatment of spotted wilt virus infected Arum Lily corms on percentage infected plants arising from them.

TABLE III

Effect of Heat-treating Virus-free Tomato Seed in Normal Atmosphere on Ability of the Seed to Germinate and on Weight of Seedling

Treatment		Number of Seeds which had germinated out of 45, 17 Days after Sowing	Average Weight of Seedling
Temperature ° F.	Duration (Days)		
120	4	44	0·125 gm.
120	8	43	0·081 gm.
120	12	44	0·081 gm.
—	—	42	0·124 gm.
120	4	45	0·116 gm.
120	8	43	0·104 gm.
120	12	44	0·107 gm.
—	—	42	0·180 gm.
120	4	43	0·168 gm.
120	8	44	0·166 gm.
120	12	45	0·152 gm.
—	—	44	0·158 gm.
150	2	45	0·124 gm.
150	4	42	0·100 gm.
150	6	44	0·095 gm.
—	—	42	0·184 gm.
150	2	44	0·122 gm.
150	4	44	0·101 gm.
150	6	44	0·104 gm.
—	—	43	0·192 gm.
150	2	45	0·142 gm.
150	4	42	0·121 gm.
150	6	45	0·117 gm.
—	—	44	0·147 gm.

The work was repeated using seeds saved in 1950 from highly infected (Potentate) plants. Table IV contains the data.

TABLE IV

Effect of Heat-treating Virus-infected Tomato Seed in Normal Atmosphere on Ability of the Seed to Germinate and on Weight of Seedling

Treatment		Number of Seeds which had germinated out of 45, 17 Days after Sowing	Average Weight of Seedling
Temperature (° F.)	Duration (Days)		
120	4	45	0·295 gm.
120	8	44	0·278 gm.
120	12	42	0·268 gm.
—	—	45	0·341 gm.
120	4	45	0·217 gm.
120	8	44	0·232 gm.
120	12	42	0·241 gm.
—	—	45	0·284 gm.
120	4	44	0·268 gm.
120	8	45	0·236 gm.
120	12	39	0·231 gm.
—	—	42	0·301 gm.
150	2	45	0·372 gm.
150	4	43	0·335 gm.
150	6	43	0·324 gm.
—	—	45	0·383 gm.
150	2	44	0·231 gm.
150	4	42	0·228 gm.
150	6	44	0·221 gm.
—	—	44	0·242 gm.
150	2	45	0·285 gm.
150	4	41	0·246 gm.
150	6	43	0·257 gm.
—	—	44	0·287 gm.

In Fig. 3 the relation between seedling weight in the case of clean seeds and of infected seeds and duration of treatment is shown for each temperature. There is little difference between the two sets of 120° F. seedling weights (seedling weight in the case of untreated seeds=1), but in the case of infected seeds the 150° F. points are considerably above those for clean seeds. It thus appears that the greater weight of seedlings from treated infected seeds when compared with the control seedlings is related in some way to the presence of virus. The infected seeds used in this year's work were a year older than the seeds used last year and probably contain less virus.

Chemical Therapy

An investigation was carried out into the possibility of chemotherapeutic control of chrysanthemum mosaic. Use was made of chemical solutions which other workers had found could reduce virus infection. The solutions were either applied to the root systems or sprayed on to the leaves.

The experimental details were as follows. The soil in each pot of 20 mosaic-infected chrysanthemum plants was watered with 100 ml. of one of the solutions on each of five days. The shoot systems of another 20 similar plants, a jaconet disc surrounding the base of the stem of each, were sprayed with the same solution on each of five days until the foliage was completely covered. One month or longer after treatment, the plants were tested for virus. Leaves from sprayed plants were immersed in water for one day just before testing in order to remove any deposit. A leaf from each of five plants was ground in the same portion of liquid. The suspension was applied to the test plants.

Table V lists the treatments and gives the results of the tests.

TABLE V

Effect of applying certain Chemicals to Mosaic-infected Chrysanthemum Plants on Virus Infection

Chemical Solution	Region Treated	Number of Groups infected one month later. A Group contains five Plants
0·00098% thiouracil	Root system	4 out of 4
0·00098% ,, ...	Shoot ,,	4 ,, ,, 4
0·025% malachite green	Root ,,	4 ,, ,, 4
0·00625% ,, ,, ...	Shoot ,,	4 ,, ,, 4
0·0125% zinc sulphate	Root ,,	4 ,, ,, 4
0·00625% ,, ,, ...	Shoot ,,	4 ,, ,, 4
Solution of fluorescein, 0·02%, and of potassium bicarbonate, 0·3% ...	Root ,,	4 ,, ,, 4
Same solution	Shoot ,,	4 ,, ,, 4
0·2% calcium chloride	Root ,,	4 ,, ,, 4
0·2% ,, ,, ...	Shoot ,,	4 ,, ,, 4
0·025% 8-hydroxy-quinoline-sulphate.	Root ,,	4 ,, ,, 4
Same solution	Shoot ,,	4 ,, ,, 4
Saturated (about 0·2%)		
2, 4-dichlorophenoxy-acetic acid.	Root ,,	1 ,, ,, 3
Same solution	Shoot ,,	2 ,, ,, 4
Same solution, diluted 15 times ...	Root ,,	2 ,, ,, 4
0·0125% hydroquinone	,, ,,	4 ,, ,, 4
0·0125% ,, ...	Shoot ,,	4 ,, ,, 4
0·0166% thiazamide	Root ,,	3 ,, ,, 4
0·0166% ,, ...	Shoot ,,	4 ,, ,, 4
Solution of sulphanilamide, 0·00415%, and of glucose, 0·00415%	Root ,,	2 ,, ,, 4*
Same solution	Shoot ,,	3 ,, ,, 4

* Tests carried out in winter.

All 2, 4-dichlorophenoxy-acetic acid treatments caused injury, but cuttings from each of the three treated groups were normal. The upper leaves of some plants sprayed with thiazamide were damaged. No other treatment injured the plants.

Only 2, 4-dichlorophenoxy-acetic acid offered any promise as a therapeutic agent.

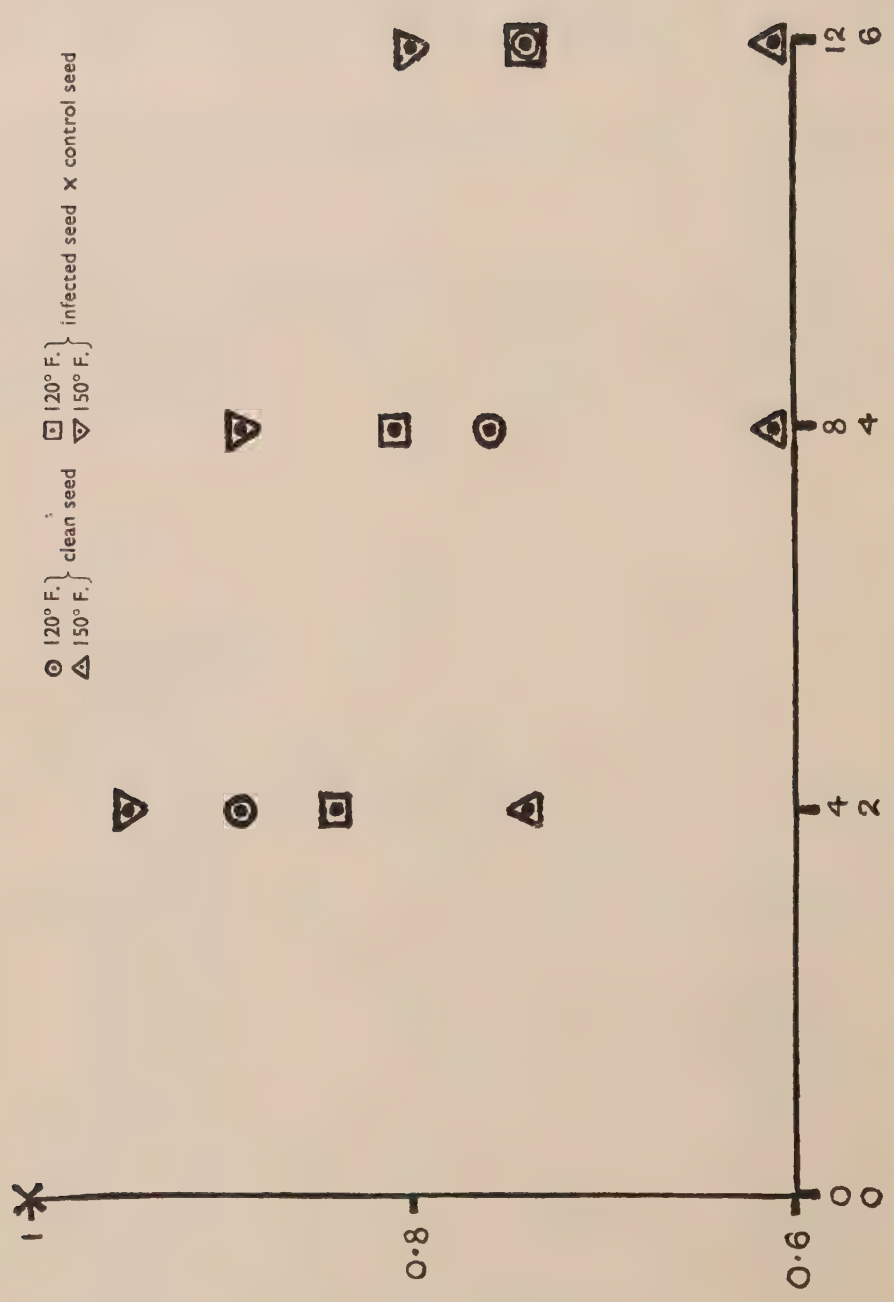


FIG. 3

The effect of heat treatment on seedling weight in the case of clean and virus infected seed.

Other Treatments

The effects of short-wave radiation and of super-sonic radiation upon the virus content of virus-infected tomato seeds and on the seeds themselves were determined. The treatments were kindly carried out by Mr. F. R. George of the Hertford County Hospital. The amount of virus in the treated seeds was compared with that in the control seeds by the half leaf method. Table VI gives the effect on lesion count and on the seed itself.

TABLE VI

THE EFFECT OF SHORT-WAVE RADIATION AND OF SUPER-SONIC RADIATION ON THE VIRUS CONTENT OF VIRUS-INFECTED TOMATO SEED AND ON THE SEED ITSELF

Radiation to which Treated Seed was Exposed	Experiment	Average of two Lesion Counts carried out on Separate Days		Average % Decrease in Lesion Count
		Treated Seed	Control Seed	
Short-wave radiation ...	1	41·0	62·0	31
	2	159·0	177·5	
	3	77·5	151·5	
Super-sonic radiation ...	1	41·5	34·5	—1
	2	10·0	18·0	
	3	28·5	22·5	

	Number of Seeds which had germinated out of 45, 17 Days after Sowing	Appearance of Seedlings	Average Weight of Seedling
Seed treated with short-wave radiation	45	Normal	0·066 gm.
Control seed	44		0·071 gm.
Seed treated with super-sonic radiation	45	Normal	0·081 gm.
Control seed	45		0·071 gm.

Super-sonic radiation had no effect on the virus content but short-wave radiation reduced the lesion count to 69 per cent.; this means a much greater reduction in virus content. There was little effect on the seed itself.

(b) Chrysanthemum Mosaic

Further work was carried out on the mechanical transmission of chrysanthemum mosaic. Possible therapeutic means of control were also investigated, as described above.

Mechanical Transmission

Chrysanthemum plants proved free from virus infection were used.

(*a*) Fifteen chrysanthemum plants dusted with carborundum were treated with chrysanthemum mosaic virus solution prepared by grinding infected *Nicotiana glutinosa* leaves in 0·5 per cent. sodium sulphite. Two months later no virus could be detected in the plants.

(*b*) Virus solution prepared as described above was caused to pass through a hypodermic needle into each of 15 plants by natural suction induced by transpiration, but two months afterwards the plants were uninfected.

(*c*) Fifteen plants which had been kept unwatered in the dark for three days were treated as in (*a*). Two months later there was no virus present in the plants.

(*d*) Potted plants were heat-treated in a moist atmosphere for one day and immediately afterwards treated with virus solution as described in (*a*). The plants were tested for virus two months later. The details of the work are contained in Table VII.

TABLE VII

ATTEMPTS AT MECHANICAL TRANSMISSION OF CHRYSANTHEMUM MOSAIC VIRUS TO HEAT-TREATED CHRYSANTHEMUM PLANTS

Number of Plants Treated	Temperature of Treatment (° F.) Duration 1 Day	Effect on the Plant itself	Date Plants treated with Virus	Number of Plants infected two Months later
15	105	Plants just survived	4/3/52	10 out of 15
8	101	Plants uninjured	19/6/52	None
8	109	„ „	19/6/52	„
8	117	Plants badly injured	15/7/52	—
8	113	Plants uninjured	16/7/52 ⎫ 12/8/52 ⎭	5 out of 15

Mechanical transmission was successful in the case of plants treated at 105° F. in late winter (March) and at 113° F. in summer. Heat treatment caused some injury of the plants but they survived if afterwards they were kept in the shade for some time. Other treatments either injured the plants too badly or did not weaken them sufficiently for mechanical transmission to occur.

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[1] HOWLES, R., Rep. Exp. Res. Sta., Cheshunt, 1951, **37**, 32–40.

[2] HOWLES, R., Rep. Exp. Res. Sta., Cheshunt, 1950, **36**, 26–34.

III. ENTOMOLOGICAL INVESTIGATIONS

RED SPIDER MITE (Tetranychus telarius L.)

By W. J. PARR, C. CROCKER, E. R. SPEYER

Summary

(*a*) Upon the foliage of growing tomato, cucumber, and carnation plants, the maximum number of eggs deposited during June by individual mated mites was about the same for each, and was in the region of 130. Mites reciprocally transferred between tomato and carnation and those transferred to tomato after having been reared upon cucumber, laid, on the average, far fewer eggs than mites which were interchanged between other combinations of the three kinds of plant.

Comparison of the average number of eggs laid upon the foliage of growing cucumber and tomato plants with that deposited upon discs cut from the leaves of these plants and kept floating on water, indicated that under the latter conditions the mites, although their normal span of life was not reduced, were deprived of some nutrient essential to the attainment of their full reproductive capacity, which was regained if they were returned to their normal habitat. It appeared possible that this nutrient, which disappeared most rapidly from tomato leaf-discs and less so from floating portions of carnation leaves than from cucumber leaf-discs might have been dissolved from the leaf tissues into the water upon which they floated.

(*b*) Upon floating leaf-discs cut from a cucumber pot-plant which had developed 16 secondary leaves below the growing-point, the greatest number of eggs were deposited upon those taken from leaves situated at a distance below the growing-point equal to about one-third the total height of the plant. The close proximity to one another of the hairs upon leaves nearer to the apex of the plant evidently prevented the mites from feeding upon the leaf surface, so that the nutrient essential to the production of many eggs was denied to them: this nutrient was probably not available in sufficient quantity to the mites upon the old leaves low down upon the plant to enable them to deposit more than a few eggs.

(*c*) Mites were reared to maturity in situ upon floating discs, on which the eggs had been laid, cut from cucumber and tomato leaves. From the proportion which developed to maturity, it was estimated that not more than 30 young mites should be kept upon a disc-area of 1 sq. in., if all are to reach the adult state, unless they are transferred to freshly-cut discs during the course of their development.

The nutrient essential to successful development disappeared more rapidly from tomato than from cucumber leaf-discs, but the quantity contained in a disc at the time of cutting was evidently dependent upon the position of the leaf on the plant from which it was taken.

The effect of temperature upon the rate of development of male mites was recorded: over-crowding appeared to accelerate rather than retard the rate for those which reached maturity.

(*d*) Some female mites, during their lifetime, were observed to be mated more than once by males. Differences were found in the colour and size of eggs laid respectively by the summer and the hibernating form of the mite.

(*e*) The percentage viability of eggs deposited during the period from late May to the end of September was greater than that for eggs laid during the earlier months of the year.

(*f*) Submergence in water of the deuteronymph resting-stage (irrespective of its age at the time) for periods up to 70 hours had no effect subsequently upon the longevity and reproductive capacity of the adult mite: submergence for 24 hours retarded the development of the adult within the deuteronymph skin, and the resting phase (period of ecdysis) was prolonged still further by submergence for longer periods of time.

(*g*) The chætotaxy of the mite in its various instars is compared with that of *Metatetranychus ulmi* Koch. As a result of preliminary examination of serial sections, the functions of the more important internal organs of the adult female mite are discussed in relation to the published accounts given by American and Continental authors.

Further observations have been recorded upon the bionomics of adult mites of the summer form by methods similar to those previously adopted (Rep. Exp. Res. Sta. Cheshunt 1951, pp. 41–49):

in addition, however, a comparison has been made of the longevity and reproductive capacity of female mites when kept respectively upon growing plants and upon detached leaves floated upon water.

(1) Mites deprived of Food and Moisture

In May and June, adult female mites collected from Datura leaves and confined in glass vials were kept in a dessicator containing calcium chloride, and others in a closed vessel containing a 41 per cent. solution of sulphuric acid to give a relative atmospheric humidity of 50 per cent.

Of 24 mites under totally dry conditions, only four were alive on the fifth and none survived after the sixth day; of 15 eggs deposited upon strands of webbing spun by the mites, six hatched with an incubation period of some nine days.

Of 24 mites kept in an atmosphere of 50 per cent. R.H., 14 were alive on the fifth, but none survived after the seventh day; of 15 eggs deposited, 11 hatched with an incubation period of some nine days.

It thus became evident that some eggs actually deposited and subsequently kept in a dry atmosphere could retain their viability, though the larvæ were observed to succumb within a few minutes after extricating themselves from the shell.

(2) Submergence in Water

Adult mites were submerged in distilled water for a period of some 30 minutes, transferred in the water to a microscope slide, and covered with a light cover-glass. The presence of air was apparent in the lumen of the peritremes and the dorso-ventral tracheæ connecting these with the main tracheal trunks, and in longitudinal grooves in the integument of the mandibular plate, extending from its apex to transverse grooves at its base. Even after submergence for more than 24 hours, these grooves still contained air.

In the case of mites transferred after 30 minutes' submergence in distilled water to a 0·01 per cent. solution of estol, air contained in the integumental grooves referred to disappeared rapidly, and persisted only in the lumen of the peritremes and dorso-ventral tracheæ. The grooves were free of air in the case of mites submerged directly in the estol solution.

About one minute after having been submerged in distilled water, the mites became quiescent, but in the estol solution they continued to move their legs vigorously for many hours.

Mites still performed these movements when disturbed after they had remained submerged either in distilled water or estol solution for periods of six to eight days, and resumed their normal activity after removal from the liquids to the surface of leaves.

In a previous experiment (loc. cit p. 44) in which a few females in the deuteronymph resting-stage had been submerged in water for a period of 24 hours, the adult mites subsequently obtained from them lived for many days but deposited no eggs.

During April female deuteronymphs in the resting-stage were collected at random from tomato plants and kept submerged in water for 24 hours. Each was then transferred to a disc cut from a cucumber leaf floating on water, an adult male mite being placed with the deuteronymph on some discs, but not on others, in order that the reproductive capacity could be recorded subsequently both for mated and unmated females. The mites were exposed to full daylight in the laboratory, and fresh leaf-discs were provided for them at frequent intervals of time. The temperatures recorded during the observations ranged from 60–73° F., with a mean of 66·5° F.

All the deuteronymphs performed the ecdysis to the adult stage after transference to the leaf-discs, and the males, where provided, were observed to pair with the females.

The details recorded in section A of Table 1 show that out of seven mites, only one failed to produce eggs, and of the remainder both the reproductive capacity and the percentage viability of the eggs deposited was equal to and indeed exceeded in most instances those of four mites obtained from deuteronymphs which had not been submerged in water, the records for which are given in section B of Table I.

During the course of this experiment, three females in the deuteronymph resting-stage were each submerged in distilled water for a period of 24 hours and transferred with three adult male mites to the leaflet of a young tomato pot-plant, which was kept in a glasshouse in which the temperatures recorded during the subsequent observations ranged from 48–104° F. with a mean of 67·7° F. In order to facilitate counting of the eggs deposited, the females were from time to time transferred to leaflets of fresh plants.

TABLE I

LONGEVITY AND REPRODUCTIVE CAPACITY OF FEMALE MITES AFTER SUBMERGENCE OF THE DEUTERONYMPH RESTING-STAGE IN WATER

Section	Deuteronymph Resting-stage			Adult Mites							Eggs Laid					
	Period of Sub-mergence (Hours)	Age at Sub-mergence (Hours)	Period to Ecdysis	No.	Condi-tion	Life span (Days)		Period to first Egg (Days)		Period of Oviposition (Days)		Total per Mite		Daily average per Mite		% Viable	
						Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
A	24	—	15 mins.	1	mated	4	—	—	—	—	—	0	—	—	—	—	—
			18 hrs.–2 dys.	4		28	20–38	7	5–10	21	14–28	45	12–73	2·24	0·7–3·1	85	64–97
			1–3 dys.	2	virgin	45	40–49	6	5–7	39	35–42	87	78–96	2·30	1·9–2·7	53	39–68
B	Nil	—	—	2	mated	20	18–23	7	—	10	6–14	16	11–12	1·60	1·5–1·8	53	38–82
				1	virgin	19	—	7	—	12	—	7	—	0·58	—	0	—
				1		7	—	3	—	2	—	2	—	1·00	—	100	—
C	24	0·5–28	15 mins.–23·5 hrs	4	mated	24	15–46	2	1–3	22	12–44	74	21–146	3·29	1·7–4·4	92	82–99
		15	18 hrs.	1		7	—	—	—	—	—	0	—	—	—	—	—
		30	nil	1		34*	—	3	—	3*	—	2	—	0·65	—	50	—
		1–15	4–20 hrs.	4	virgin	32	20–40	3	2–5	28	17–35	68	33–109	2·50	1·1–3·4	93	91–95
		0·5	<18 hrs.	1		3	—	—	—	—	—	0	—	—	—	—	—
		29·5	25 mins.	1		59*	—	2	—	5*	—	4	—	0·80	—	25	—
D	Nil	—	—	1	mated	56*	—	2	—	5*	—	6	—	1·20	—	17	—
				2	virgin	>13	>12–15	2	—	10	—	30	28–32	3·16	2·8–3·6	80	57–100
E	32	19	18 hrs.	1	virgin	27	—	2	—	23	—	44	—	1·90	—	95	—
	40	9–23	8–24 hrs.	2		25	—	3	—	21	—	40	—	1·90	—	94	—
	48	<18	22–47 hrs.	3		7	5–9	5	—	2	—	3	—	1·10	—	37	—
	70	<18	25 hrs.	3		>18	13–>21	7	—	12	6–15	19	—	1·60	—	76	—

* Mite assumed colour of hibernating form.

Of the three female mites obtained from these deuteronymphs, one died during the first 10 days, and the other two lived respectively for 20 and 33 days; in all 89 eggs (an average of 30 per mite) were laid, of which 80 per cent. were viable.

Of three females kept under similar conditions but obtained from deuteronymphs which had not been submerged in water, one died during the first nine days, and the other two lived respectively for 10 and 16 days; in all 61 eggs (an average of 20 per mite) were laid, of which 72 per cent. were viable.

In order to determine whether submergence in water at any particular period in the development of the deuteronymph resting-stage might subsequently affect the reproductive capacity, female deuteronymphs in the *active* stage were kept upon floating discs cut from tomato leaves and allowed to enter the resting phase. At progressively increasing intervals of time ranging from one half to 30 hours after they had been observed to enter the resting phase (the latter period closely corresponding with the age at which unsubmerged deuteronymphs were observed to perform the ecdysis to maturity) the deuteronymphs were submerged for a period of 24 hours in water at 70–72° F., and were then transferred to floating discs cut from cucumber leaves. The observations were recorded during August at temperatures during the life of the adult mites ranging from 57–84° F. with a mean of 70° F.

After removal from the water, only two out of 16 deuteronymphs failed to perform the ecdysis to maturity; both had entered the resting phase 10 hours prior to the time of submergence. One deuteronymph which had been in the resting phase for 30 hours performed the ecdysis during the process of submergence.

Details of the result of this experiment are given in section C of Table I, and in section D corresponding records for mites kept under similar conditions, the deuteronymphs of which had not previously been submerged. As indicated in the table, some of the adult mites after depositing a few eggs assumed the red colouration of the hibernating form and lived for many days without further reproduction.

In late August and again in October, deuteronymph resting-stages of approximately known age were submerged in water for more prolonged periods of time ranging from 32–70 hours. The females obtained from them being kept under conditions similar to those obtaining in the previous experiments except that all were unmated. The temperatures recorded during the observations ranged from 61–73° F. with a mean of 65° F.

The details given in section E of Table I, when compared with those of the previous experiments, indicate that neither the reproductive capacity nor the viability of the eggs deposited had been reduced even by the longest period of submergence.

Such was the degree of variation in the longevity and reproductive capacity of the mites used in these experiments, that it was found necessary to show separately in Table I the records for those which lived only for a few days and deposited few or no eggs; these females, it is thought, might have succumbed as a result of some pathological condition.

It was concluded that submergence of the deuteronymph resting-stage in water for periods of time up to at least 70 hours had no subsequent effect either upon the longevity and reproductive capacity of the mites obtained from them, or upon the viability of the eggs deposited.

From the experiments in which the deuteronymphs were submerged at known periods of time after they had entered the resting-phase, it became possible to determine at least approximately to what extent the period occupied in that stage had been prolonged. In August, the average duration of the resting-stage for deuteronymphs which were not submerged in water was computed to be in the region of 33 hours.

The records given in Table II show that submergence for 24 hours caused an approximate average prolongation of 15 hours (range 10–16 hours) for those which had entered the resting-phase from 30 minutes to 24 hours prior to submergence, and of about 20 hours for those which normally would have performed the ecdysis not more than five hours before they were submerged.

Not included in the table is the record for one deuteronymph submerged one hour after entering the resting phase, which did not perform the ecdysis for a period of 43 hours after it had been removed from the water; this gave an approximate prolongation of no less than 35 hours, but the adult mite subsequently behaved in a normal manner and deposited 41 eggs, the first laid two days after the ecdysis. Only 27 of these eggs, however, hatched and the percentage viability of 66 was considerably lower than that of eggs obtained from all other mites, mated or unmated, used in the experiment: furthermore, 25 larvæ hatched from them all developed later to adults of the male sex, indicating that mating of the parent female had been ineffective.

TABLE II

Effect of Submergence in Water upon Duration of Deuteronymph Resting-stage. All Periods in Hours

Period of Submergence	Age at Submergence	Period after Submergence to Ecdysis	Total Duration of Resting-stage	Approximate Period of Prolongation
24	0·5	23·50	48·00	15·00
	1	23·50	48·50	15·50
	3	21·25	48·25	15·25
	6	19·00	49·00	16·00
	15	4·00	43·00	10·00
	24	1·25	49·25	16·25
	28	0·25	52·25	19·25
	29	0·50	53·50	20·50
	30	0·00	30·00	—
32	19	18	69	36
40	9	24	73	40
	23	8	71	38

Also given in Table II are the records for deuteronymph resting-stages submerged for longer periods of time. Since the age of these and the period of submergence together considerably exceeded the normal duration of the resting phase, and ecdysis was not performed for from eight to 24 hours after removal from the water, it follows that submergence had a retarding effect upon the development of the adult mite within the deuteronymphal skin.

Still greater prolongation of the resting phase was recorded in deuteronymphs which were submerged for 48 and 70 hours respectively at the end of October, but details are not included in Table II, because the normal period for the resting phase could not be determined at the time. For deuteronymphs up to 18 hours from entry into the resting phase, the period from termination of submergence to ecdysis was respectively 22–47 hours after 48 hours, and 25 hours after 70 hours of submergence.

(3) Longevity and Reproductive Capacity upon Growing Plants

In previous investigations (Rep. Exp. Res. Sta. Cheshunt, 1951, pp. 44–46) information was obtained upon the longevity and reproductive capacity of mites kept upon leaves or portions of them detached from the plant and floated upon water. There were indications that the mites usually laid fewer eggs upon floating leaves of tomato than upon those of carnation and cucumber.

The following observations are the result of an attempt to obtain similar information upon female mites of the summer form during their life respectively upon the foliage of living carnation, tomato, and cucumber plants, and to record differences, if any, in their reproductive capacity when transferred from one to the other.

In order to confine the mites to restricted areas upon the plants, a ring of vaseline was smeared round the stalk of the leaf or leaflet or the base of the leaf upon which they were situate, and to facilitate, if not to render possible counting of the eggs deposited by them, the mites were transferred after convenient intervals of time either to other leaves of the same plant or to another plant as nearly as possible of the same age. In all cases comparatively young plants were made use of, viz. tomato (var. Potentate) with five to eight, cucumber with not more than seven leaves expanded, and in the case of carnation, cuttings which had been rooted some four months previously and had attained a height of 7 to 9 ins. When placed upon the upper surface of foliage, the mites nearly always moved to the lower surface within a few minutes. Sometimes, but not often, disturbances occasioned by transference from one leaf to another, even of the same plant, resulted in escape of the mite, which would fall from the leaf-surface upon a thread of webbing; in one instance a number of females in succession escaped from the carnation leaf to which they had recently been transferred from the foliage of a tomato plant.

In order to record the percentage viability of the eggs, the leaf or leaflet upon which they had been deposited was removed from the plant and kept floating on water—

(*a*) Preliminary Observations

In March, three females collected at random from a cucumber plant were transferred to the leaflet of a tomato plant; after four days the mites had deposited 15 eggs, of which some were mishapen or shrivelled and only six proved to be viable. Upon another leaflet of the same plant to which they were transferred and remained for another period of four days, they deposited 15 eggs; three of these were laid upon the upper surface of the leaflet by a female which died during this period. The two surviving mites, after transference to the leaflet of another tomato plant lived for two days, during which they deposited five eggs.

Over the total period of 10 days, the three mites, deposited in all 35 eggs, at a daily average rate of 1·25 per mite; of these 25 (71 per cent.) hatched subsequently with an average incubation period of 16·6 (range 16–18) days; temperatures over this period ranged from 58–69° F. with a mean of 63·5° F.

One mite near the termination of its life when collected evidently deposited the majority of those eggs which subsequently failed to hatch.

Since the rate of oviposition over the total period during which the mites remained alive was quite regular, it became apparent that the disturbance caused by transferring them from one leaflet to another, or from one plant to another had not impaired their reproductive capacity.

At the end of March a single female mite, together with the three moulted skins of its adolescent life and 31 eggs which it had laid, was located upon the leaflet of a tomato plant in a heated glasshouse. The mite was kept for successive periods of time upon tomato leaflets under the varying conditions here listed, and deposited the stated number of eggs during each:—

(1) Three days on the original leaflet floated on water at 63° F. in the laboratory—three eggs.
(2) Two days on a fresh leaflet floated on water at 63–64° F. in the laboratory—five eggs.
(3) Five days on the leaflet of a growing plant in an unheated glasshouse, with mean temperature 61·7° F. (range 50–90° F.)—15 eggs.
(4) Five days on another leaflet of the same plant in the laboratory, with mean temperature 65·1° F. (range 61–67° F.)—12 eggs.

The mite lived for one day more after termination of the last period, having deposited in all 66 eggs. Since the first of these, laid upon the original leaflet, was observed to hatch three days after the latter was detached from the plant and the period of incubation for the 31 eggs ranged from 9–15 days, it was estimated that the total period of oviposition had extended over some 24 days.

The average number of eggs deposited upon the original leaflet before its detachment from the plant was computed as 4·4; this was reduced to 1·6 during periods (1) and (2) upon the floating leaflets, rose again to 3·0 during period (3) upon a growing plant, finally falling slightly to 2·4 as the mite approached the end of its life in period (4), during which all the eggs were laid upon the upper surface of the leaflet.

All the eggs were viable, except one of the last deposited during period (4), with incubation periods and mean temperatures recorded during them respectively of 12–15 days at 63·5° F. in (1) and (2), 8–10 days at 66·0° F. in (3), and 7–9 days at 66·4° F. in (4).

Three larvæ from eggs deposited on the original leaflet, and six from those laid during period (4) were reared to maturity; all were males, and it is therefore probable that the female mite was unmated.

From these observations it appeared probable that, as a result of keeping it upon leaflets detached from the plant, the mite had been deprived of some nutrient essential to the attainment of its full reproductive capacity, which was regained when the mite was returned to its normal habitat.

(*b*) Reproductive Capacity Upon Different Kinds of Host-Plant

In previous experiments (loc. cit p. 46) in which mites were confined upon portions of leaves kept floating on water, there had been a tendency for them to deposit fewer eggs upon those of tomato than upon those either of cucumber or carnation, irrespective of which of these plants they had previously been reared on.

During May and June an attempt was made to determine whether this applied also to mites living upon the foliage of growing plants.

Female mites in the deuteronymph resting-stage were collected respectively from cucumber, tomato, and carnation plants; immediately after reaching maturity, each mite together with an adult male was transferred to a leaf or leaflet of each kind of plant, and confined to it by encircling the stalk or base with vaseline.

After it had remained for a convenient period of time upon the leaf or leaflet, each female mite was transferred to another upon the same plant; the one from which the mite had been removed was detached from the plant and kept floating upon water in order to facilitate counting of the eggs, in a few instances subsequently to determine their percentage viability and, by rearing to maturity some of the nymphs, to determine whether or not the females had been mated.

The plants were kept in a glasshouse in which, at least over the major period of the experiment, the recorded temperatures ranged from 54–104° F. ,with a mean of 72·9 °F.

All mites previously reared upon each kind of plant readily established themselves on plants of the same kind and upon cucumber plants; this was also the case with mites transferred to carnation after having previously been reared upon cucumber. Of seven mites reared upon carnation, five established themselves upon tomato; the other two, each of which remained alive for a period of some six days only and deposited two eggs, were deemed to have been in an unhealthy condition not caused by change of host-plant. Of four mites previously reared on cucumber, two would not remain upon the leaflets of tomato, and of six reared upon tomato only two established themselves upon the leaves of carnation.

The mites which established themselves in their new habitat deposited their first eggs on the second day after ecdysis from the deuteronymph stage. After a period of some 10 to 20 days upon any particular kind of plant, there was a general tendency for the mite, after having deposited a few eggs upon the upper surface or at the edge, to escape from the leaf or leaflet upon which it had most recently been placed by falling to the foliage beneath upon a strand of webbing. Such behaviour was taken as an indication that the mite had approached the natural termination of its life.

The details given in Table III relate only to those mites which established themselves upon the foliage of the plants to which they had been transferred. For mites previously reared upon carnation and transferred to tomato, the life-span and period of oviposition were respectively shorter and the average number of eggs deposited was less as compared with those of mites in all the other categories.

TABLE III

Longevity and Reproductive Capacity of Mites upon Growing Plants

Reared Upon	Transferred to	Females: No.	Females: Life Span (Days) Mean	Females: Life Span (Days) Range	Females: Period of Oviposition (Days) Mean	Females: Period of Oviposition (Days) Range	Eggs Laid: Total per Mite Mean	Eggs Laid: Total per Mite Range	Eggs Laid: Daily Average per Mite
Cucumber	Tomato	2	15·5	14–17	13·0	11–15	72·5	37–108	5·6
	Cucumber	2	>15·0	>9–>20	13·5	8–19	87·5	51–124	6·5
	Carnation	3	>18·0	>16–>20	16·7	14–19	67·0	59–72	4·0
Tomato	Tomato	3	16·0	14–18	14·3	12–17	99·7	73–127	7·0
	Cucumber	2	>14·0	>9–>19	13·0	8–18	90·5	51–130	7·0
	Carnation	2	>15·0	—	14·0	—	52·5	38–67	3·7
Carnation	Tomato	5	10·2	10–11	8·2	8–9	38·8	12–55	4·7
	Cucumber	4	18·7	15–24	14·2	8–20	67·7	45–92	4·8
	Carnation	5	>16·4	>7–>26	15·0	6–24	89·2	36–134	5·9

The reproductive capacity was highest and approximately the same (an average complement of about 90 eggs) for mites reared upon one kind and transferred to the same kind of plant, and for those reared upon tomato and transferred to cucumber, but rather lower (67) for those reciprocally transferred between cucumber and carnation. For mites reared upon cucumber and transferred to tomato, and for the reciprocal transference between tomato and carnation, the reproductive capacity was lowest of all. In the former instance only two of the four mites used in the experiment established themselves, so that the true average for the number of eggs deposited and the daily average should become respectively 36·25 and 2·78; in the latter instance the corresponding figures for mites reared upon carnation and transferred to tomato, remain respectively as 38·8 and 4·7, but in the reverse transference between these two plants, only two out of six mites established themselves, so that the true averages became respectively 17·5 and 1·25.

A high proportion of the eggs deposited upon all the plants were viable. The viability of samples from mites previously reared upon carnation was, on cucumber (162 eggs) 98 per cent., on tomato (33 eggs) 97 per cent., on carnation (129 eggs) 92 per cent., the average period of incubation being nine days (range 6–11 days) at a mean temperature of 69° F. (range 63–85° F.); some nymphs were

reared to maturity upon the leaves or leaflets, floated on water, upon which the eggs had been laid, and the adult mites obtained were, on cucumber 28 males, 70 females, on tomato one of each sex, on carnation 17 males and 23 females. The presence of females in the samples indicated that the parent females had been mated. Nymphs from only two eggs deposited upon tomato by a mite considered to be in an unhealthy condition both developed to males.

When the records set out in Table III are compared with those previously obtained for mated mites kept upon leaves detached from plants and floated on water (loc. cit. p. 47, Table III), it becomes apparent that for the former the life-span was generally of rather *shorter* duration but the number of eggs deposited by mites which became established upon the plants to which they were transferred was much greater, except in the case of those reciprocally transferred between cucumber and carnation, in which it was approximately the same (between 60 and 70 eggs per mite).

It is probable, therefore, that the mites were deprived of some nutrient essential to the production of eggs by detachment of foliage from the plant and that this was most pronounced in the case of tomato and least so in that of carnation. There is also a possibility that this nutrient might have been dissolved out of the leaf by the water upon which it was floated, and that the waxy nature of carnation foliage to some extent prevented this.

(4) Reproductive Capacity upon Leaves of Varying Age

During September, female mites were kept upon discs ½ in. in diameter cut from the leaves of a cucumber plant and floated lower surface upwards on water.

The plant had been raised from a seed germinated in early July, and the soil of the pot containing it was given liberal dressings of a mixed fertilizer. At the time of the experiment, conducted in the laboratory at a mean temperature of 63·8° F. (range 57–80° F.), the plant had developed 15 leaves below the growing-point, the cotyledons and first secondary leaf having died off; the female mites made use of in it had been reared from the egg upon portions of cucumber leaves floated on water, and had recently become adult after ecdysis from the deuteronymph stage.

The leaf-discs, upon each of which a single female together with a recently mature male was placed, were cut from leaves situated at different levels upon the plant, and each female was transferred after a uniform interval of time to a fresh disc cut from the same leaf.

Upon the first disc cut from each leaf the mite was allowed to remain for a period of five days, and upon the second for one of four days; since sufficient material was no longer available after the third disc had been cut from each selected leaf, the mites remained upon the latter for periods up to 15 days. Of the six female mites used, that upon the discs cut from the lowest leaf, the tissues of which deteriorated rapidly when they were floated on water, was discarded after a period of eight days, and another upon discs cut from the third leaf below the growing-point died after a period of 21 days; the remainder were still alive on the twenty-second day when the experiment was concluded.

During the intervals of time between which the discs were cut from each selected leaf, changes naturally took place in the area of its surface through growth, and consequently in the proximity of the leaf-hairs to one another. The lower surface of the first leaf below the growing point, and therefore the youngest, was densely beset with hairs for the period during which the first two discs were cut from it, and less so when the third was taken. Throughout the course of the experiment the leaves from the third to the tenth below the growing-point were of a dark green colour with the hairs less dense, those from the latter to the twelfth lighter green, and the lowest three leaves were yellowing with the hairs far apart or wanting.

The details given in Table IV show that the greatest number of eggs, and highest average laid daily, were deposited by the mite kept upon discs cut from the seventh leaf below the growing-point, and at levels above and below this there was a fairly uniform reduction.

It thus became apparent that the mites upon discs cut from the younger leaves toward the apex of the plant were unable to pierce the hairy surface by means of their stylets, so that lack of essential nutriment was responsible for their low reproductive capacity; this contention was indeed borne out by the fact that a period of no less than 13 days elapsed before the mite upon discs cut from the youngest leaf deposited its first egg. From the oldest and yellowing leaves the mites were evidently unable to obtain this nutrient in sufficient quantity to enable them to produce many eggs.

Differences in the viability of the eggs, also shown in the table, deposited upon discs cut from the leaves at varying levels are not considered to be significant. The average period of incubation for the 110 eggs which hatched out of the total of 134, was 12·8 days (range 11–15 days) at a mean temperature of 63·8° F.

TABLE IV

Reproductive Capacity on Cucumber Leaves of Varying Age

Female Mite	Number of Leaf below Growing-point from which Discs were Cut					
Period in Days:	1st	3rd	7th	10th	13th	15th
Upon leaf-discs	22	21	22	22	22	8
From ecdysis to first egg	13	3	3	4	5	7
Of oviposition	10	15	19	19	13	1
Number of eggs deposited	8	30	47	34	14	1
Average number of eggs laid daily ...	0·8	2·0	2·5	1·8	1·1	–
% viability of eggs	100	90	89	69	71	0

It was concluded that the reproductive capacity of the mite is entirely dependent upon the quantity of essential nutrient which it can obtain from the leaf tissues and that density of hairs upon the leaf-surface may prevent it from gaining access to this nutrient.

(5) Development of Young Stages upon Floating Leaf-discs

(*a*) Proportion reaching Maturity

In August eggs were obtained from mites, both mated and unmated, during the first 12 days of their period of oviposition upon discs, ½ in. in diameter, cut from cucumber leaves and floated on water. The discs were cut from leaves situated at a distance below the growing point equal to about one-third the height of the plant.

After a period of 3–5 days upon the first, each female mite was transferred to a second disc, upon which it was kept for a period of 4–5 days, and finally, in most instances to a third disc on which it remained for 2–5 days.

The development of the young mites which subsequently hatched from the eggs was allowed to proceed in situ upon each disc.

The average period of time from cutting and floating of the discs to hatching of the first egg upon each was nine days (range 7–13 days): the first of those mites which succeeded in completing their development reached maturity after the discs had been floating, on the average, for 19 days (range 15–25 days), and the last ones after a corresponding period of 25 days (range 18–30 days).

The mean temperature recorded during development of the young stages to maturity was 68° F. (range 57–84° F.).

Of a total of 180 young obtained from six mated females, 99 (55 per cent.) developed to maturity: of the adult mites 22 were males and 77 females. Upon each of 16 discs the average number of eggs hatched was 11 (range 1–30), and that of the mites which subsequently reached maturity was six (range 1–14).

Of a total of 226 young obtained from eight unmated females, 178 (79 per cent.) developed to maturity: all the adult mites were of the male sex. Upon each of 20 discs the average number of eggs hatched was 11 (range 1–28), and that of the mites which subsequently reached maturity was nine (range 1–23).

In Table V, in which details of these observations are recorded, the discs upon which the young mites hatched from the eggs upon them are divided into three categories, holding respectively 1–10, 11–20, and 21–30 young mites: in the columns beneath each of the latter are given the total number of eggs hatched (i.e. the initial number of young mites), the number of young which reached maturity, and the percentage of the initial number which developed to maturity, the progeny of the mated females being divided between the sexes and totalled for comparison with that of the unmated females, all the offspring of which developed to adults of the male sex.

An examination of the percentage columns shows that in all three categories the proportion of young, obtained from unmated females, which developed successfully to adult males, was the same (about 80 per cent.): there was naturally some variation upon individual discs, on one of which, holding nine young, none, and on another, holding 15 young, all developed to maturity, but development was complete for all upon discs holding up to seven young.

TABLE V

Development of Young Stages on Floating Leaf-discs of Cucumber

Young Mites		Number of Eggs Hatched on each Disc								
		1–10			11–20			21–30		
Progeny of	Reaching Maturity	Eggs Hatched	No.	%	Eggs Hatched	No.	%	Eggs Hatched	No.	%
Mated females	Males		10	18		8	11		4	7
	Females		30	56		41	57		6	11
	Total	54	40	74	72	49	68	54	10	18
Virgin females	Males	66	51	77	88	71	81	72	56	78

For the progeny of mated females, which comprised both sexes in proportion of one male to 3·5 females, the percentage of young reaching maturity was about 70 upon discs holding from one to 20, but only 18 on those holding 21–30 young: all the young mites developed to maturity upon discs holding up to six young. This indicated that the young of mites destined to become females required more nutrient than those which were to become males, since the separate percentages for the mites of each sex, allowing for their proportion to one another, were computed to be the same (about 40). Upon individual discs, the smallest number of mites reaching maturity was two (both females) out of 24 young, and the largest was 14 (two males and 12 females) out of 18 young; it is possible that the developing females tended to crowd out the males upon discs holding considerable numbers of young. As in the case of the male progeny from unmated females, such variation was considered to be due to differences in the amount of nutriment contained in the leaf, or portion thereof, at the time at which the disc was cut.

While the above observations were being recorded, an unmated female mite was kept under similar conditions upon floating discs of the same size but cut from tomato leaflets.

During the period of five days for which it was kept upon the first disc, the mite deposited 14 eggs, the first of which hatched 11 days after the disc was cut: all the eggs were viable, but none of the young mites developed beyond the protonymph (active) stage, the last of which succumbed after the disc had been floating for a period of 25 days.

Upon the second disc, on which it remained for four days, the mite laid 17 eggs, the first of which hatched after nine days; all the eggs were viable, but only six young developed to adult mites, all of the male sex: the first mite reached maturity after the disc had been floating for a period of 17 days, and the last after a corresponding one of 25 days.

Upon the third disc, only one egg was laid, and the young mite which hatched from it after eight days developed to an adult male when the disc had been floating in all for a period of 19 days. Thus out of a total of 32 young, only seven (22 per cent.) reached maturity, and all of these upon discs which had been floating for periods of less than 20 days.

It was concluded that the nutriment essential to the support of the young mites during their development to maturity disappeared more rapidly from floating discs cut out of tomato leaflets than from those cut out of cucumber leaves, and probably that at the time at which the discs were cut, the former contained less of this nutriment than the latter.

(b) Rate of development

The duration of development from hatching of the egg to attainment of maturity was recorded for those mites which reached the adult stage upon floating leaf-discs of cucumber in the foregoing experiment.

The results are set out in Table VI, in which the temperatures recorded during development of the mites are arranged in ascending order of the absolute means with the duration of development, for the sexes separately, opposite each. If the mean rates of development for the males are plotted against the mean temperatures, which vary sufficiently, the result is nearly a straight line, but not quite, the curvatures evidently to some extent being due to fluctuation in the rate of development for some mites upon discs on which larger numbers and females in addition were present: over-crowding indeed seemed to accelerate rather than retard the rate of development. It would appear that between mean temperatures of 66° F. and 69° F., the rate of development for male mites was

accelerated by about two days for every degree rise in mean temperature. Owing to the comparatively small differences in the mean temperatures (67–70° F.) recorded during development of the female mites, it was not possible to observe the effects (if any) of rise in temperature upon their rate of development.

TABLE VI

Duration of Development from Hatching to Maturity on Floating Cucumber Leaf-Discs

Temperatures °F.				Mites reaching Maturity		
				No.	Period of Development in Days	
Mean	Mean Max.	Mean Min.	Range	Males	Mean	Range
66·1	72·7	62·8	57–84	32	14·47	11–18
66·4	73·3	63·1		22	13·80	9–18
67·3	73·2	64·0		29	12·10	7–17
67·6	73·2	64·4		45	11·17	8–16
67·7	73·0	64·6		47	10·15	7–15
68·8	74·2	65·7	59–84	19	8·63	8–13
69·7	74·3	66·2		4	8·00	7– 9
72·3	77·6	68·6	64–84	1	8·00	—
				Females		
67·2	73·1	63·9	57–84	9	11·40	9–18
67·6	73·2	64·4		36	12·07	8–17
67·7	73·1	64·6	59–84	15	11·80	9–14
68·7	74·2	65·6		16	12·00	9–16

(5) Viability of Eggs at different Seasons

From records obtained during experiments carried out from April to October, and described above, it became possible to gain some information as to any fluctuation which might occur in the viability of eggs deposited at different seasons.

Ample evidence has been obtained to the effect that, within reasonable limits, the conditions under which the eggs are laid and kept during the period of incubation have no influence upon their viability. In Table VII the records given apply only to eggs obtained from female mites, whether mated or unmated, which deposited 30 or more eggs apiece; the figures indicate that during the earlier months of the year, the viability, especially for eggs laid by unmated females, was considerably lower than that obtaining from towards the end of May even until the end of September, when other females were assuming the red colour of the hibernating form before laying any or after depositing only a few eggs, the great majority of which, incidentally, were not viable.

TABLE VII

Seasonal Differences in Viability of Eggs

Female Mites			Eggs			Period of Incubation (Days)		Temperature °F. during Oviposition	
Period of Oviposition	No.	Condition	No. Laid	No. Hatched	% Viability	Mean	Range	Mean	Range
11 IV–24 V ...	3	mated	167	143	85·6	9·9	7–12	66·1	60–78
	2	virgin	174	95	54·6	9·9	8–13	66·7	
23 V–13 VI ...	5	mated	322	308	95·6	9·3	6–11	67·8	54–88
15 VIII–27 IX ...	3	mated	275	258	93·8	7·9	5–13	69·4	57–84
	6	virgin	346	316	91·3	8·3	5–16	68·8	

Of a total of 166 eggs which failed to hatch in April, the shells of 83 became indented and later the eggs collapsed; at least three others collapsed a few hours after they had been deposited. Within the shells of the remainder, some development of the embryo was discernible, and in a few instances the young mite reached a stage in which the eye-spots were visible.

(6) Biological Notes

During experiments with mites upon floating cucumber and tomato leaf-discs in early April, five females were observed to be mated by males: the pairings took place immediately after, or within two hours of the females having completed the ecdysis from the deuteronymph stage.

The sexes remained in coitu for from four to seven minutes.

Upon the foliage of a tomato plant, two females which had reached maturity 24 hours previously were observed to be mated by two of three males which had been placed on the same leaflet with them, and with which they remained in coitu for seven to nine minutes: respectively five and 65 minutes after the first mating, the two females were observed to be paired again, the sexes in both cases remaining in coitu for a period of five minutes.

Late in August, a female mite was reared from hatching of the egg to maturity upon a floating cucumber leaf-disc, development occupying a period of 11·5 days. The mite, which became adult on September 5th was somewhat darker in general colour than the normal summer form; unmated, it was transferred to a fresh leaf-disc upon which it began to oviposit four days later. After the mite had laid 14 eggs over a period of eight days, a male mite was placed with it, and pairing was effected immediately, the sexes remaining in coitu for a period of some six minutes. During the ensuing period of 23 days the female laid 43 eggs, after which it died, having survived in all for 35 days upon the leaf-discs which had been renewed at frequent intervals of time.

Of the 57 eggs deposited, 51 (89 per cent.) subsequently hatched; two larvæ obtained from eggs laid by the female prior to being mated both developed to adult males in a period of 15 days, but only two young from eggs laid after the female had been paired succeeded in reaching the deuteronymph stage, in which the sexes are first distinguishable from one another, and both of these were again males.

These observations prove that the female mite may be paired more than once during its life, and indicate that pairing may take place after it has deposited a considerable number of eggs by parthenogenetic reproduction.

In April, both mated and unmated females deposited their first egg, on the average, 6·5 days (range 3–10 days) after ecdysis from the deuteronymph stage. In August, the corresponding period was 2·4 days (range 1·5–3 days) for mated, and 2·6 days (range 1·5–5 days) for unmated females.

Eggs laid by females of the summer form were usually of a pearly white colour and measured 130–140μ in diameter; the small number of those obtained from mites which assumed the red colouration of the hibernating form in late September, were of a dark brown colour and had a diameter of only 100–108μ, and few of them were viable.

In late August, a female of the summer form deposited one of these small brown eggs as its first, some two days after it had reached maturity, but the eggs laid subsequently were of the larger size, and as more were produced, so they became paler in colour.

In April, adult males, of unknown age at the time of collection, kept on floating cucumber and tomato leaf-discs remained alive for periods of 16–35 days. In August, three males survived respectively for 42, 41, and 25 days upon floating cucumber leaf-discs.

It was computed from observations upon more than five males that the average span of life was at the very least 35 days.

Upon the foliage of growing plants, the greatest number of eggs deposited by a single mated female during June was: on carnation 134, on cucumber 130, and on tomato 127. Upon floating leaf-discs the corresponding numbers were: for mated females, in April 73 on cucumber, 11 on tomato, in August 146 on cucumber; for unmated females, in April 96 on cucumber, seven on tomato, and in August 109 on cucumber, 32 on tomato.

(7) External anatomy

Since no precise information appeared to be available as to the chætotaxy (i.e. the number, structure, and arrangement of setæ upon the integument) of the Red Spider mite which infests cucumber, tomato, and carnation grown under glass in this country, specimens in various stages of development collected from these plants and mounted in gum-chloral media have been carefully examined. While this work was being carried out, C. A. Blair and J. R. Groves (Journal of Horticultural Science, Vol. 27, No. 1, pp. 14–43, 1952) published a fully illustrated account of the chætotaxy for the Fruit Tree Red Spider-mite (*Metatetranychus ulmi* Koch) to which that of *Tetranychus telarius* is now found to bear a very close resemblance.

In *T. telarius*, as in *M. ulmi*, the trunk in *dorsal* aspect is beset with 13 pairs of setæ in all the instars of both sexes; the shafts of these setæ, however, do not appear to be pilose, as they are in *M. ulmi*. Upon the trunk in *ventral* aspect, following the numbering given by Blair and Groves (loc. cit. p. 29, fig. 8), the seta-pairs represented in the successive instars of *T. telarius* are:—

1st instar (larva): Nos. 3, 4, 8, 15, 16, 17.

2nd instar (protonymph): Nos. 1, 2, 3, 4, 5, 7, 8, 11, 15, 16, 17.

3rd instar (deuteronymph): Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 17.

Adult male and female: Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17.

Pair No. 14, present in all the instars and in the adults of *M. ulmi*, is wanting in *T. telarius*, but as in the former mite, pair No. 12 makes its appearance for the first time in the adult mites of both sexes.

(8) Internal anatomy

Some attempt has been made to study the internal anatomy of the mite from serial sections of the adult female, both of the summer and hibernating form.

As fixatives, Carnoy and Lebrun's acetic alcohol (equal volumes of absolute alcohol, glacial acetic acid, and chloroform, with or without mercuric chloride to saturation) has given satisfactory results, but Bouin's picro-formal has also proved adequate. As with other Acarines, the obtaining of good serial sections is to some extent a matter of chance, owing, at least in the case of this particular mite, to the hard and brittle nature of the integument. For staining, Heidenhain's hæmatoxylin differentiated by the long method with iron alum, with acid fuchsin as a counterstain was employed with success, but some good results were also obtained by simple staining with Ehrlich's hæmatoxylin.

From a preliminary examination of the sections obtained, it would appear that the most recent and comprehensive account given by W. E. Blauvelt (Mem. 270, Cornell Univ. Agr. Exp. Sta. Ithaca, New York, 1945) might require some revision in respect of the functions attributed to the pharyngeal pump, the "fat-body," the ventriculus (main digestive organ), and the dorsal excretory organ.

From its position in relation to the mouth opening, the pharyngeal pump would appear to function as a piston for expelling some kind of fluid from the mouth, and not (C. F. Blauvelt, loc. cit., p. 10) for sucking in nutriment from the plant tissues: the œsophageal valves, which doubtless prevent the return to the pharynx of fluid contained in the ventriculus, occur in other mites which possess no pharyngeal pump. From observation of living mites under slight pressure, it is suggested that the pump is used mainly for the expulsion of the fluid which forms the silk strands.

With reference to the so-called "fat-body", the presence of such an organ in Acarines has been denied at least by the majority of previous authors. Taking into account the vast amount of webbing which is spun by *Tetranychus telarius* L., and the comparatively small size of the paired tubular glands from which the silk-fluid is evidently secreted, it is tentatively suggested that the very large compact organ which forms a cortex surrounding the main nerve ganglion and which extends into the proximal segments of the palpi, might function as a reservoir for the silk-fluid, though admittedly no connection between this organ and the silk-glands has as yet been demonstrated.

There must remain some doubt as to whether or not the "reniform silk-glands" may have the function of true salivary glands.

The ventriculus appears to be of more complex structure than is described by Blauvelt: from its central portion, into which the œsophagus opens, two forwardly directed diverticula, not referred to by that author, pass to either side of the mandibular plate.

The lumen of the ventriculus, in the summer but not in the hibernating form of the mite, is partially and sometimes almost entirely filled with large and free digestive cells which, as described by Sig Thor (Annales des Sciences Naturelles, Zoologie, ser. 8, Vol. 19, Paris 1903) are budded off from cells lining the walls of that organ. Blauvelt (loc. cit., p. 11) refers to these digestive cells as "round or oval masses of food material" and gives them the name of "food balls."

On account of its very small diameter, it would not be possible for any but the very smallest grains of solid matter to pass through the œsophagus, and these digestive cells have a diameter (about 15–25μ) at least four times that of the œsophagus in its passage through the main nerve ganglion, in the tissue of which it could not be subject to enlargement through muscular action. Incidentally, some of the cells have been kept under observation in a living mite submerged in water

over a period of 13 days (see Rep. Exp. Res. Sta. Cheshunt, 1951, p. 43): measurements under a magnification of about 350 taken at successive intervals of time showed neither reduction in their diameter, nor appreciable change in the colour of their contents.

The presence or absence of any direct connection between the ventriculus and the dorsal excretory organ has been a matter of dispute amongst Continental authors, the majority of which deny its existence. Blauvelt (loc. cit. p. 12 and figs. 11 and 12), on the other hand describes and figures such a connection, though this is by no means obvious in his fig. 12 on Plate 2. So far, no connection has been traced in the sections examined, though in one series what appears to be the remnant of a broken-down digestive cell is situated anteriorly in the lumen of the excretory organ. In the case of the mite referred to above, no material was observed to pass directly from the ventriculus into the excretory organ during its 13 days' submergence in water.

The extremely large and highly differentiated ventricular cells which immediately adjoin and partially surround the dorsal excretory organ evidently collect the waste products in liquid form from the lumen of the ventriculus and pass them on to the single layer of cells which constitute the walls of the excretory organ; the latter cells would elaborate and finally secrete these products as urates, which would crystallise to form solid excretory pellets in the posterior portion of its lumen. Thus any direct connection, at all events of a permanent nature, between digestive and excretory organ would be of no physiological use to the mite and might involve the loss of both food and digestive cells from the ventriculus.

IV. INSECTICIDES AND FUNGICIDES

By W. H. READ, R. J. SMITH and J. T. HUGHES

1. Laboratory Investigations

(a) Acaricides

Investigations of the ovicidal properties of certain phenylhydrazones and 4-chlorophenylhydrazones of benzaldehyde and certain chlorinated benzaldehydes, have not disclosed any compounds of merit as ovicides against eggs of the glasshouse Red Spider (*Tetranychus telarius*). Substitution of chlorine in the *para* position of either phenyl group of benzaldehyde phenylhydrazone reduced ovicidal action. Substitution in both *para* positions caused an even greater reduction in ovicidal activity. *p*–Chlorophenylhydrazine is, however, more ovicidal than phenylhydrazine at equimolecular concentrations and is a moderately potent ovicide against eggs of *T. telarius*.

With oximes of aldehydes or ketones containing one or two phenyl groups, chlorine substitution in the *para* position in the phenyl groups increased ovicidal activity. 4:4′-Dichlorobenzophenone oxime was considerably more toxic than 4-chlorobenzophenone oxime, and benzophenone oxime was not toxic. The substitution of chlorine in the 2- position influenced the ovicidal action of benzaldoxime much less than substitution in the 4- position.

Chlorine substitution in the 4-position of one phenyl group of benzylideneaniline appeared necessary to obtain high ovicidal activity. 4-chlorobenzylideneaniline was somewhat more ovicidal than benzylidene-4-chloroaniline. 4-Chloroaniline and 4-chlorobenzaldehyde were slightly more toxic than the corresponding non-halogenated compounds.

In view of the divergent results obtained by various workers from investigations on the ovicidal activity of chlorinated phenyl benzenesulphonates towards eggs of various species of mites, additional laboratory tests have been carried out in order that the results can be examined in more detail.

(b) Fungicides

The investigations of the fungitoxic and phytotoxic activities of compounds related to quinones, for example the chlorinated derivatives of certain dihydroxy-, diamino- and aminohydroxy- benzenes and naphthalenes, and their acetyl esters, have been continued. This work has involved the synthesis of many compounds for examination in *in vitro* spore germination tests, and against tomato leaf-mould (*Cladosporium fulvum*) and tomato stem-rot (*Didymella lycopersici*) in preliminary glasshouse trials.

(c) Chemical

Investigations of problems of residues arising from the use of toxic chemicals for the control of diseases and pests in glasshouses were commenced in 1952 but progress was seriously interrupted by changes in staff. Considerable advances were made towards the end of the year in developing satisfactory methods for the determination of certain insecticidal residues, and in particular of parathion residues. Some determinations of residues of parathion resulting from applications of smokes and aerosols have been made but additional confirmatory determinations are necessary before any reliable statement about such residues can be published.

Preliminary work on the distribution of pest control chemicals within glasshouses when applied as smokes and aerosols has been undertaken.

2. Glasshouse Investigations

(a) Cucumber Mildew Control

(1) Screening Trials

Preliminary trials with a number of fungicides for the control of cucumber mildew (*Erysiphe cichoracearum*) were commenced in 1951 and further tests have been carried out during the past year in an attempt to find promising materials for more extended trials. The method of testing was that described in the Annual Report for 1951, a copper oxychloride-petroleum emulsion mixture being used as a standard fungicide with which to compare the candidate fungicides.

The substances tested as fungicides, unless otherwise stated in the following list, were the commercially pure compounds. In most cases Lissapol N at 0·1 per cent. was employed as a wetting agent; the exceptions are indicated in the list.

(*a*) Standard copper-petroleum mixture—an admixture of a proprietary copper oxychloride suspension and a proprietary petroleum emulsion. The spray contained 0·06 per cent. w/v Cu. and 0·35 per cent. w/v petroleum. No addition of wetting agent was made to this spray.

(*b*) "Thiofide"—stated to be dibenzthiazyl disulphide.

(*c*) ' Z676 '—stated to be 2 : 4-dinitrophenylbenzthiazyl sulphide.

(*d*) ' Cyclocure '—stated to be *cyclo*hexylbenzthiazyl sulphenamide.

(*e*) Tetramethyl-thiuram-monosulphide.

(*f*) ' Karathane W.P.25 '—a proprietary formulation containing 25 per cent. of the active material 2:4-dinitro-6-caprylphenyl crotonate.

(*g*) Phygon—a proprietary product containing 50 per cent. of 2:3-dichloro-1:4-naphthaquinone.

Results

The control of cucumber mildew obtained with Karathane was outstanding since at 0·025 per cent. w/v equivalent to 0·006 per cent. of active material it was superior to the control given by the copper oxychloride-petroleum emulsion spray. The latter was representative of the copper-petroleum spray mixtures which are widely employed commercially for the control of cucumber mildew. The safety of Karathane on cucumbers is doubtful however. Severe mottle and distortion of expanding leaves and hardening of young shoots ("breaks") was caused at concentrations exceeding 0·1 per cent. w/v. No damage was discerned at 0·025 per cent. but the tests with Karathane were made on plants which were somewhat hardened due to growth at low temperatures and to the mildew, and which may thus have been rendered less susceptible to damage.

Very promising control of mildew was obtained with the proprietary product containing 2 : 3-dichloro-1 : 4-naphthaquinone but this material was not obtained in time to carry out phytotoxicity trials. Some indication was obtained that the compound may not be as toxic in this formulation as in the laboratory formulation tried in 1951.

No other compound showed sufficient merit to qualify for more extensive trials. Severe damage to cucumbers was caused by *cyclo*hexyl-benzthiazyl sulphenamide at 0·1 per cent. and by zinc mercaptobenzthiazole at 0·1 per cent.

Cucumber Mildew Sprays

Date	Spray Treatment	Mean percentage Leaf Area with Living Mildew on Leaves visibly infected when Sprayed		Mean percentage Leaf Area mildewed on Leaves not visibly infected when sprayed 18 Days after Spraying
		When Sprayed	18 Days after Spraying	
20/8/52	Standard copper-petroleum mixture ...	20	10	3
	Thiofide, 0·2%	25	>40	>40
	„ 0·1%	23	>40	>40
	Z676, 0·2%	15	>40	23
	„ 0·1%	14	>40	20
22/8/52	Standard copper-petroleum	15	2	2
	Cyclocure, 0·2%	35	7*	4*
	„ 0·1%	8	23*	3*
	Bantex, 0·2%	15	—*	—*
	„ 0·1%	37	>40*	6*
2/9/52	Standard copper-petroleum	30	4	1
	Tetramethyl-thiuram monosulphide, 0·2%	23	>40	10
	„ 0·1%	33	>40	33
	Phygon, 0·1%	34	2	1
	„ 0·03%	18	8	2
29/9/52	Standard copper-petroleum	25	10	5
	Karathane, 0·2%	36	2·5	0
	„ 0·1%	28	2	0
	„ 0·05%	31	2·5	1

* Damage to cucumber plants resulted from these fungicide applications.

(2) Glasshouse Trials with Zineb

In addition to the preliminary screening tests with pot plants to sort out promising fungicides, two trials were made in which a zineb (zinc ethylenebis(dithiocarbamate)) preparation, ' Dithane Z78,' was compared with a copper petroleum mixture for the control of cucumber mildew on crops of melons and cucumbers. Zineb was the only compound apart from 2 : 3-dichloro-1 : 4-naphthaquinone, which showed merit in preliminary trials in 1951.

In all these trials the Dithane was used at a dilution of 1 lb. in 60 gallons (equivalent to 0·11 per cent. w/v zineb) and the copper-petroleum spray contained 0·06 per cent. Cu as copper oxychloride and 0·35 per cent. petroleum as an emulsion conforming to the specification for Stock emulsion petroleum summer washes for glasshouse use. [1]

In both trials the distribution and severity of the disease was uniform throughout the glasshouses in which all the plants were sprayed with either the zineb or copper-petroleum sprays, and in consequence only two replicates of each treatment per house were employed. In view of the nature of the disease no control plots, which would have entailed considerable financial loss, were considered necessary.

Two applications were made to the cucumbers at an interval of 10 days. The results of the tests were disappointing since whilst both sprays appeared to have given equal control of the fungus when the plants were examined five days after the first spraying, a further examination made 10 days after spraying showed that the redevelopment of mildew from diseased areas was very much more extensive on the plants sprayed with the zineb preparation than on those sprayed with the copper-petroleum mixture, and also that new areas of infection were more numerous. Furthermore, the deposit from the zineb preparation was so apparent after a single application that its removal from cucumber fruits prior to marketing would be essential. In view of this disfiguration of the fruits together with the obvious superiority of the copper-petroleum mixture in controlling cucumber mildew the trial was discontinued.

In the trial on melons the same conclusions were reached as a result of the examination of the plants 10 days after spraying. It would appear that in order to obtain satisfactory control of cucumber mildew under normal glasshouse conditions, applications of Dithane Z78 at intervals of not more than one week would be required. The very noticeable deposits on the fruit would render this impracticable.

Acknowledgements are due to Messrs. Monsanto Chemicals Ltd., Messrs. Charles Lennig Ltd., and the Insecticide & Fungicide Co-ord. Service of the A.R.C. for supplying samples for these trials.

(b) Soil Sterilization with Chloropicrin

The relative values of chloropicrin, steam, and formaldehyde for the partial sterilization of glasshouse soils were compared in a trial in which there were four replications of each treatment. In order to minimise the influence of shade, temperature and other factors which arise in glasshouses, the glasshouse (100 ft. by 15 ft.) was divided into four blocks by transverse and longitudinal section and each block was subdivided into four equal plots to accommodate the three treatments and a control receiving no sterilization treatment.

The soil in the glasshouse, a medium loam, was thoroughly dug and all lumps were broken down to give as even a tilth as possible. The "steamed" plots were sterilized by the "Hoddesdon-Pipe" method, the steam being injected into the soil at a depth of 10 ins., the soil temperature being raised to 210° F. and being maintained at that temperature for 15 minutes.

The "chloropicrin plots" were injected with chloropicrin on January 11th by injecting 3·5 ml. amounts of chloropicrin at a depth of 6 ins. and at spacings of 12 ins., the injections being staggered in alternate rows. The surface of the soil in each chloropicrin plot was sealed after treatment, by treading the surface and watering to wet the surface inch of soil. The rate of application of chloropicrin was 560 lbs./acre.

The "formaldehyde plots" were treated on January 14th by watering on a 0·78 per cent. w/v solution of formaldehyde (1 part of commercial 37·5–40·5 per cent. formaldehyde to 49 parts of water) at the rate of 5 galls. per sq. yd. No treatment was applied to the control plots at this stage.

Prior to planting all the plots were thoroughly flooded and a uniform application of fertilizer applied throughout the house and forked into the soil. Tomatoes, variety Ailsa Craig, were planted throughout the glasshouse on March 1st and the same cultural conditions given to all the plots throughout the season.

TABLE I

Results: Yields of Tomatoes—Tons per Acre

Block No.	*Control*	*Steam*	*Chloropicrin*	*Formaldehyde*
1	44·0	43·9	46·1	39·7
2	38·5	41·4	60·9	42·7
3	37·5	49·6	45·4	40·4
4	44·2	44·8	45·9	40·0
Mean	41·0	44·9	49·6	40·7

Significant difference at P=0·05=9·12·
„ „ „ P=0·1 =7·45

The yields of tomatoes from the various plots are tabulated. Owing to the variations between the yields obtained from plots within treatments, the increased yield of the chloropicrin treated plots cannot be regarded as significant (at P=0·05). With the exception of the yield from one plot treated with chloropicrin, the yields from the plots were in all cases lower than those from the corresponding plots in 1951, as is shown in Table II.

TABLE II

Percentage Increase or Decrease in Yields, 1952

Block No.	*Control*	*Steam*	*Chloropicrin*	*Formaldehyde*
1	—16	—16	—12	—24
2	—23	—18	+32	—15
3	—30	— 8	—16	—39
4	— 7	— 6	— 3	—16
Mean	—19	—12	+0·25	—23·5

Examination of the results suggests that some factor or factors, possible those responsible for the overall reduction of yields in 1952 in comparison with the yields for 1951, were such that no reliable information can be obtained from this trial. The results suggest, however, that treatment with chloropicrin was probably as effective as steaming. The absence of any benefit from treatment with formaldehyde is contrary to the usual result of such treatment and is indicative of the presence of some abnormal factor influencing crop yield.

(c) Systemic Insecticides for Red Spider Control

The application of systemic insecticides to planted out tomatoes must be regarded as too hazardous until much more information is available regarding their persistence in the plants and in the soil.

The possibility of treating tomato plants whilst in 3-in. ("60") pots and shortly before planting them out, and so "loading" them with the systemic insecticide that overwintering mites arriving on the plants would be destroyed and infestation of the plants prevented, was investigated, however.

Batches of young tomato plants in 3-in. pots were watered on March 18th with 25 mls. of solutions of Pestox III, a proprietary product containing bis(dimethylamino)phosphonous anhydride (schradan) and triphosphoric penta(dimethylamide) as the main active ingredients, and ' Isopestox,' a proprietary product stated to contain bis(mono*iso*propylamino)fluorophosphine oxide as the active ingredient. The concentrations employed with both products were 1 per cent., 0·5 per cent., and 0·25 per cent., hence the amounts of insecticidal material per plant were 0·25, 0·12 and 0·06 grammes. The treated plants together with untreated control plants were potted up into 10-in. pots on March 20th and placed in randomised positions in a tomato house in which plants heavily infested with spider were grown the previous year.

Examination of the plants on April 7th disclosed that mites were feeding on the plants and that considerable numbers of eggs had been laid. No difference was observed later between the build-up of mite infestation on any of the plants. Injury was observed five days after treatment on plants which were treated with Pestox III. The damage was confined to the scorching of the tips of the serrations of the leaflets, i.e. at points where guttation occurs most readily. The effect was very pronounced on plants receiving 0·25 g. Pestox III and only slight on plants receiving 0·06 g. No injury was observed on plants treated with ' Isopestox.' Subsequent growth of all plants was normal.

The results of this test indicate that the prevention of infestations of tomato plants by Red Spider through the destruction of adult female overwintering mites which gain access to the plants is unlikely to be achieved by the application of systemically acting acaricides to the soil in the pots from which they are planted out. Whether acaricidal action is absent in the plant tissues 18 days after its addition to the soil, as a result of its breakdown within the plant tissues, or as a result of dilution through the rapid growth of the plants, or is due to some other cause has not been determined.

(d) Tomato Leaf-mould

The control of tomato leaf-mould (*Cladosporium fulvum*) is not easily accomplished by existing fungicides when climatic and cultural conditions are favourable to its development. Furthermore, the substitution of petroleum emulsions by other means of controlling Red Spider, has removed the advantages of the relatively expensive copper-petroleum mixtures. More effective fungicides are being sought, therefore, and the potentialities of certain quinones and related compounds have been investigated. Many of these compounds have been synthesised in the laboratory and this work has been commenced in extension of more fundamental laboratory investigations.

The most promising of the compounds tested, 4-amino-2-chlorophenol, gave, as a 0·25 per cent. spray, control equal to that given by a copper oxychloride-petroleum spray containing 0·06 per cent. Cu and 0·35 per cent. petroleum. In these preliminary trials 4-amino-2-chlorophenol exhibited high eradicant activity. Variable results were obtained in phytotoxicity tests with this compound but effective concentrations may not be too phytotoxic for practical use. Preliminary tests conducted late in the year indicated that certain derivatives of 4-amino-2-chlorophenol may be less phytotoxic than the parent compound without being appreciably less effective fungicides and such compounds will be further investigated in trials with tomato leaf-mould during the coming year.

(e) Tomato Stem-rot (Didymella lycopersici)

Severe losses continue to result from attacks of *Didymella*, and investigations on the control of this disease by the application of chemicals have been continued, particularly in an effort to find an effective eradicative fungicide. During the past year preliminary tests have been made in which fungicidal pastes were applied to *Didymella* lesions on tomato stems.

Of the compounds tested so far only certain organo-mercurial compounds showed promise in arresting the development of lesions when tested on plants about 2 ft. in height. The concentrations required were high, however, and in view of the high toxicity of the compounds it will be necessary to investigate possible hazards arising from their use. Furthermore, additional tests on older plants are required to assess the merits of these compounds under commercial conditions.

REFERENCE

[1] "Specifications and Methods of Analysis for certain Insecticides, Fungicides and Herbicides." Min. of Agric. (Lond.) Tech. Bull. No. 1, 2nd ed., 1951, p. 26.

V. CHEMICAL INVESTIGATIONS

1. EXAMINATION OF SOME HOOF AND HORN MATERIALS

By G. W. WINSOR and M. I. E. LONG

As previously described in the Annual Report for 1950[1] and elsewhere,[2] comparative tests made on a group of bone meals revealed marked variability in the properties of their nitrogenous constituents. This variability was ascribed not only to differences in origin of the samples but also to biological decomposition during storage. From the results obtained it was apparent that, so far as the nitrogenous constituents of bone materials were concerned, considerable differences between samples could arise in horticultural practice. Bone meals cannot be regarded as a major source of nitrogen, however, and experiments with other nitrogenous materials were therefore made. For this purpose 41 samples of hoof and horn were obtained, the countries of origin including India, Brazil, Mexico, Australia, Nigeria, Syria and Lebanon, Norway and Great Britain. It had originally been intended to study these materials in three groups, namely hoof, horn, and commercial mixtures of the two. Examination soon showed, however, that preliminary heat treatment of some of the materials by the manufacturers considerably altered their properties. The samples were accordingly separated into two groups, all those which had received any form of preliminary heat-treatment being referred to as "calcined" as distinct from the original raw materials. The results for raw and calcined hoof and horn are presented separately in this report, followed by a comparison of the data for the two groups.

The samples as received differed considerably in appearance, the raw horn materials containing fibrous matter in some cases up to 2 ins. in length. To reduce these gross physical differences between the samples all the materials were milled through a 1-mm. grid before testing. The following tests were made on the milled samples:—

(1) Total nitrogen. (Kjeldahl.)
(2) Initial rates of decomposition in the soil by incubation for seven days.
(3) "Availability" of nitrogen in the soil by incubation for 10 weeks.
(4) Water-soluble nitrogen.
(5) Hydrolysable nitrogen.
(6) Ammonia by distillation with magnesia.
(7) Soluble nitrogen by formol titration.
(8) Bulk density.
(9) Sieve analysis.

Full details of these tests will be published elsewhere. The determination of hydrolysable nitrogen was applied only to the raw samples of hoof and horn, the content of water-soluble nitrogen being in this case too low to serve as a guide to the initial rates of decomposition in the soil. In this test samples of the fertilizers were heated with dilute sulphuric acid in an autoclave, the nitrogen brought into solution being determined by the Kjeldahl procedure. For test No. 7, applied to the calcined samples only, aqueous extracts of the fertilizers were titrated with dilute alkali in the presence of formaldehyde. Two series of seven-day soil incubation tests were made with different batches of a market garden soil, these being subsequently referred to as soil tests A and B.

Results obtained with Raw Hoof and Horn

The results of tests made on raw samples of hoof and horn are given in Table I. The nitrogen content of the samples showed considerable uniformity, the values ranging from 13·48 to 15·72 per cent. In the seven-day soil incubation tests of series A from 6–40 per cent. of the total nitrogen of the samples was converted to ammonia and nitrate, raw hoof being far more readily decomposed than horn at first. In a short incubation test such as this the results give a useful indication of the relative rates of decomposition in the soil, but the actual values obtained depend largely on the microbiological activity of the soil used. In a further batch of soil (series B) used at a later date hoof again proved to be more rapidly decomposed than horn, though in general all the samples showed greater mineralisation of nitrogen than in series A. The availability of the nitrogen of the hoof and horn samples, as measured by determination of ammonia and nitrate in the soil after incubation for 10 weeks, ranged from 64 to 81 per cent. of their total nitrogen. The mean values for hoof, horn,

TABLE I

THE RESULTS OF TESTS MADE ON 22 SAMPLES OF RAW HOOF AND HORN

Sample	Number	Total Nitrogen (%)	% Mineralisation of Nitrogen*			Water-soluble* Nitrogen (%)	Hydro-lysable* Nitrogen (%)	Bulk Density g./c.c.	% Passing 30-mesh Sieve
			Seven-day Incubation		10-week Incubation				
			Series A	Series B	Series C				
Mixed hoof and horn ...	1	14·82	24·0	24·0	74·9	3·7	32·4	0·27	71·7
,, ,, ,, ,, ...	2	15·38	19·7	25·4	75·0	1·0	30·5	0·24	82·0
,, ,, ,, ,, ...	3	14·37	32·6	30·4	73·5	2·1	39·6	0·47	94·7
,, ,, ,, ,, ...	4	14·27	19·4	22·0	64·2	1·7	32·0	0·25	87·7
,, ,, ,, ,, ...	5	15·01	31·2	29·6	80·6	1·1	38·7	0·29	87·8
,, ,, ,, ,, ...	6	14·72	26·6	29·5	71·4	1·4	38·5	0·40	91·1
,, ,, ,, ,, ...	7	15·35	19·1	21·8	71·4	1·3	26·3	0·20	79·2
,, ,, ,, ,, ...	8	14·97	21·4	23·0	68·7	1·2	38·9	0·22	85·1
,, ,, ,, ,, ...	38	14·24	24·4	29·0	75·3	4·7	44·1	0·33	88·7
,, ,, ,, ,, ...	42	14·60	11·8	17·1	70·2	0·8	31·5	0·16	63·9
Hoof	17	13·97	31·1	30·7	75·7	1·3	33·6	0·43	91·4
,, ...	18	14·96	29·5	30·4	76·6	1·3	31·7	0·32	85·8
,, ...	19	14·00	16·2	22·2	74·3	1·4	21·8	0·27	98·5
,, ...	20	15·46	35·4	44·9	78·6	1·3	39·4	0·48	94·0
,, ...	21	15·64	37·1	35·3	72·6	1·9	43·2	0·46	86·4
,, ...	22	15·55	40·1	35·8	75·2	1·6	42·0	0·46	89·9
,, ...	23	15·72	32·0	32·4	75·5	1·7	40·7	0·53	87·5
Horn	27	13·48	8·5	20·8	72·8	0·9	27·0	0·14	67·8
,, ...	28	14·60	12·7	22·6	73·2	0·7	27·7	0·18	80·5
,, ...	29	14·58	10·9	19·1	73·9	0·5	23·7	0·29	98·5
,, ...	30	14·82	7·2	19·3	74·7	0·4	31·1	0·32	93·0
,, ...	41	14·61	6·0	17·8	72·1	0·5	29·0	0·15	61·3

* Expressed as a percentage of the total nitrogen of the samples.

and commercial mixtures of the two materials were 75·5, 73·3, and 72·5 per cent. respectively, the general mean being 73·7 per cent. Variation between different samples of either hoof or horn alone was relatively small, but greater variability was found among the mixed hoof and horn samples. Good agreement between duplicates was found in this incubation test, the significant difference between samples being 2 per cent. (P=0·05). The content of water-soluble nitrogen in the raw samples was low, being less than 1 per cent. of the total nitrogen of the horn materials and less than 2 per cent. of the hoof. The determination of water-soluble nitrogen has often proved to be a useful guide to the initial rates of decomposition of organic materials in the soil, but in this case the values were clearly too low for this purpose. Tests were accordingly made to establish more drastic conditions under which the nitrogen of hoof and horn materials could be brought into solution, partial hydrolysis with dilute sulphuric acid in an autoclave being finally adopted. From 22 to 44 per cent. of the total nitrogen of the samples was brought into solution in this test, the values for hoof in general exceeding those for horn. As will be shown later, these results were found to be significantly correlated with the percentage of nitrogen mineralised in soil tests A and B. The bulk density of the samples showed a considerable range of values of from 0·14 to 0·53 g./c.c. In general the bulk density of milled hoof considerably exceeded that of horn, as might be expected from the fibrous nature of the latter.

TABLE II

Correlation between the Seven-day Soil Incubation Tests and other Properties of Raw Hoof and Horn Materials

Tests	*Correlation Coefficient*	*Significance*
Soil test A. % Hydrolysable nitrogen	r=+0·762	P=0·001
,, ,, ,, Bulk density	+0·878	0·001
,, ,, ,, % passing 30-mesh sieve	+0·445	0·05
,, ,, ,, Soil test B	+0·903	0·001
,, ,, B. % Hydrolysable nitrogen	+0·715	0·001
,, ,, ,, Bulk density	+0·833	0·001
,, ,, ,, % passing 30-mesh sieve	+0·460	0·05

Correlations between the Various Tests made on Raw Hoof and Horn

The chemical and physical tests described in the preceding section were chosen as possible guides to the rate and extent of mineralisation of the nitrogen of hoof and horn materials in the soil. Correlation coefficients calculated between the initial rates of mineralisation of nitrogen (soil tests A and B) and certain of the remaining tests are given in Table II, together with their levels of significance. The factor found to give the highest correlation with rate of decomposition in the soil was bulk density, the correlation coefficients being significant at P=0·001. Despite this highly significant result the existence of a positive correlation in this instance was somewhat unexpected. It might in general be anticipated that low bulk density would be related to high surface area and thus to relatively rapid attack by soil micro-organisms. Results in accord with this hypothesis were previously obtained with bone materials, whereas the reverse relationship is found in the present group of hoof and horn samples. In the case of hoof and horn, however, the explanation is probably related to the amount of fibrous material present. Milled horn materials in particular contain much fibrous material which combines low bulk density with relatively high resistance to rapid biological decomposition in the soil. A further test found to be significantly related to the rates of decomposition of hoof and horn in the soil was the determination of hydrolysable nitrogen in the samples. Correlations between soil tests A and B and the percentage of hydrolysable nitrogen were in both cases significant at P=0·001. Though the experimental conditions of this test were quite arbitrarily chosen, the high correlation with the soil tests suggests some analogy between the susceptibility of hoof and horn materials to biological transformation and to combined chemical and physical decomposition in the autoclave. That the preliminary milling of the samples before testing did not entirely eliminate effects due to particle size is shown by the correlations between sieve analyses and soil tests A and B; the percentage of each sample passing a 30-mesh sieve was significantly correlated with the results of both series of soil tests at the 5 per cent. level. Despite the differences in biological activity previously noted in the soil used, a high correlation was found between the A and B series of soil tests, the coefficient r being 0·903, significant at P=0·001.

As shown in Table II the initial rates of decomposition of hoof and horn materials in the soil, as measured by incubation for a period of one week, were significantly correlated with various other properties measurable in the laboratory. For the 10-week incubation tests, however, planned as a

measure of the ultimate "availability" of nitrogen in the samples, no such correlations have as yet been found. For samples of hoof and of horn separately the main feature of these "availability" tests is in fact the lack of variation from sample to sample. Among the mixed samples of hoof and horn the limits of variation were somewhat greater, being from 64·2 to 80·6 per cent. of the total nitrogen of the samples. Much of this variability is due to samples 4 and 5, however, these giving the lowest and highest values respectively among the 22 materials tested.

The effect of Particle Size upon the Decomposition of Hoof and Horn Materials in the Soil

Despite milling through a 1-mm. grid before testing, the particle size of the resulting products was found to be significantly correlated with the initial rates of decomposition of the hoof and horn materials in the soil, as discussed in the previous section. Further experiments were accordingly made to test the effect of particle size in different sieved fractions of hoof and horn materials upon their decomposition in soil. For this purpose relatively coarse samples of hoof and horn were milled after a preliminary sieving to remove the finer constituents originally present. The products were separated by sieving into six fractions ranging from 20–30 mesh to material passing a 100-mesh sieve. Determinations of nitrogen in the various sieved fractions showed them to be reasonably homogeneous in composition. Preliminary incubation tests in soil showed that, whereas the initial rates of mineralisation of nitrogen increased with fineness of grinding, the coarsest samples ultimately showed the highest percentage mineralisation in the soil. The latter result was quite unexpected, and more detailed tests were made with sieved fractions of hoof. The results obtained are shown in Fig. 1. For the first 11 days of incubation the percentage of the added nitrogen mineralised at each date of sampling increased consistently with the fineness of the particles. At the thirteenth and eighteenth days mineralisation of nitrogen was greatest in the middle ranges of particle size. By the thirty-ninth day the initial order was reversed, the finest particles showing the lowest "availability" in the soil. A full explanation of these results has not yet been established. It is possible, however, that the most finely ground materials, being the most rapidly attacked by the soil organisms in the early stages, cause the greatest increase in the numbers of these organisms. The proportion of the added nitrogen transferred into cell-substance or relatively resistant organic products of its decomposition may thus be greatest for the finest particles.

Tests on Calcined Hoof and Horn

With the exception of the determination of hydrolysable nitrogen, all the tests already described in this report were also applied to 19 samples of calcined hoof and horn materials, the results being given in Table III. The total nitrogen content of the samples ranged from 12·98 to 14·94 per cent., of which from 2·6 to 29·6 per cent. was soluble in water. Soluble nitrogenous compounds are thus an important constituent of calcined hoof and horn, over half the samples examined in this work containing more than 10 per cent. of their nitrogen in soluble forms. The two lowest values recorded in this test were found for samples known to have received only mild heat-treatment at 300° F. All the samples examined yielded small amounts of ammonia on distillation with magnesia, the values ranging from 1·3 to 4·8 per cent. of the total nitrogen. The presence of ammonia in the samples suggest biological decomposition in storage, as was previously found for bone materials. A rapid test in which aqueous extracts of hoof and horn were titrated with dilute alkali in the presence of formaldehyde, this procedure sometimes being described as "formol titration," gave results very similar to the ammonia as determined by distillation. The bulk densities of the samples ranged from 0·28 to 0·69 g./c.c., the two lowest values being found in samples known to have received only mild heat-treatment. The initial rates of mineralisation of the nitrogen of the samples were measured by incubation for seven days in the soil, these tests being made at the same time as the A and B series already described for the raw samples. The percentage mineralisation of nitrogen ranged from 9·0 to 46·3 per cent. in series A, and from 14·5 to 45·1 per cent. in series B, the lowest value in each case being found for a lightly calcined sample of horn (No. 37). It was previously concluded that in general the nitrogen of raw horn materials was more slowly mineralised than that of raw hoof. No such general conclusion is possible for the calcined samples, however, the calcined horn materials including not only the lowest but the highest values in these tests. As a measure of the ultimate "availability" of calcined hoof and horn materials further samples were incubated in soil for 10 weeks. Mineralisation of nitrogen in these tests ranged from 62 to 76 per cent. of the total nitrogen added. Mean values for mixed hoof and horn, hoof alone and horn alone were 69·8, 72·9, and 68·2 respectively, the mean for all samples being 70·0 per cent. Thus in general the availability of hoof slightly exceeded that of horn, but the difference was not very marked. Finely ground hoof and horn materials thus form a relatively homogeneous group of nitrogenous fertilizer with respect to their ultimate availability in the soil, though not in their initial rates of decomposition.

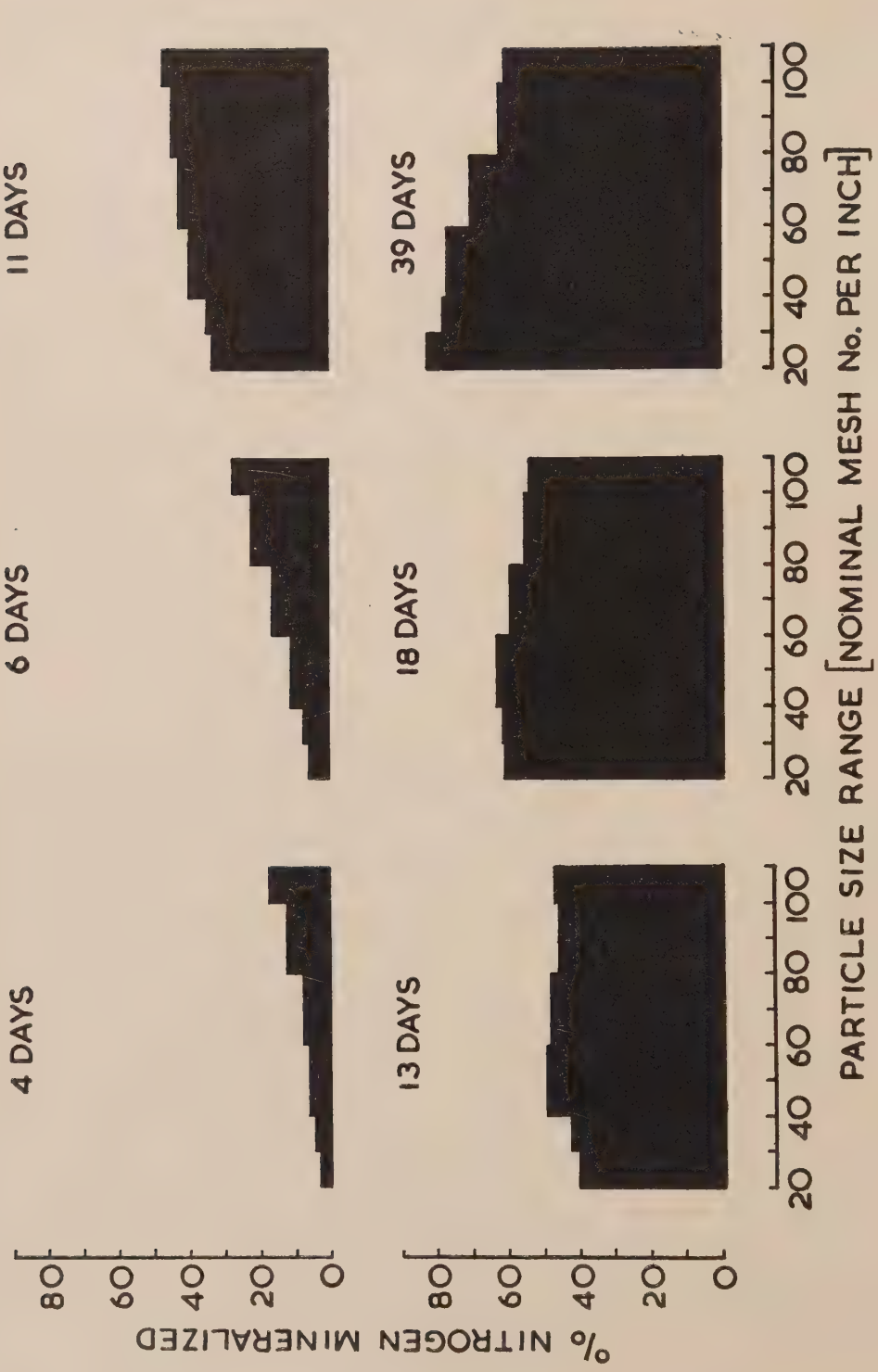

Fig. 1

Mineralisation of the nitrogen of different sieved fractions of hoof on incubation in the soil.

TABLE III

Results of Tests made on 19 Samples of Calcined Hoof and Horn

Sample	Number	Total Nitrogen (%)	% Mineralisation of Nitrogen*			Water-soluble* Nitrogen (%)	Ammonia-Nitrogen* (%)	Nitrogen* by Formol Titration	Bulk Density g./c.c.	% Passing 60-mesh Sieve
			Seven-day Incubation		10-week Incubation					
			Series A	Series B	Series C					
Mixed hoof and horn	9	13·28	27·2	27·0	66·6	13·7	2·92	2·82	0·64	76·8
,, ,, ,, ,,	10	14·08	26·8	36·4	70·8	8·8	2·23	1·78	0·63	75·5
,, ,, ,, ,,	11	14·29	32·3	33·2	69·4	12·2	3·61	2·26	0·62	74·9
,, ,, ,, ,,	12	13·38	27·0	27·5	67·4	11·7	2·37	2·35	0·58	84·8
,, ,, ,, ,,	13	14·00	22·9	24·5	70·7	7·4	1·74	1·54	0·61	60·4
,, ,, ,, ,,	14	13·39	32·6	32·9	68·9	14·7	3·23	2·68	0·66	73·4
,, ,, ,, ,,	15	14·94	27·5	30·9	73·0	8·1	1·64	1·74	0·58	78·2
,, ,, ,, ,,	16	13·25	39·3	38·0	72·3	29·6	4·81	5·00	0·64	87·4
,, ,, ,, ,,	35	13·90	21·3	26·0	67·4	4·1	1·82	1·51	0·47	66·6
,, ,, ,, ,,	39	12·98	38·1	40·8	71·8	9·5	2·04	1·85	0·69	70·2
Hoof	24	14·95	28·6	33·0	71·9	6·0	1·67	1·49	0·57	68·9
,, ...	25	14·09	29·8	34·8	74·5	6·7	2·07	1·95	0·65	69·2
,, ...	26	15·10	31·5	35·9	75·9	7·6	2·50	1·68	0·62	75·5
,, ...	36	13·16	33·8	36·6	69·2	7·6	1·96	1·74	0·59	69·0
Horn	31	14·63	17·7	22·0	67·0	7·6	1·33	0·85	0·64	71·3
,, ...	32	14·94	18·3	21·4	62·0	11·2	1·32	1·40	0·60	83·0
,, ...	33	13·06	33·4	39·9	67·1	18·7	3·62	3·22	0·65	86·4
,, ...	37	14·80	9·0	14·5	73·7	2·6	1·54	0·51	0·28	57·8
,, ...	40	14·29	46·3	45·1	71·2	21·7	3·09	3·30	0·66	80·4

* Expressed as a percentage of the total nitrogen of the samples.

Correlations between the Various Tests made on Calcined Hoof and Horn

The correlation coefficients between soil tests A and B and the other properties investigated are given in Table IV; no significant correlations have been found with the results of the 10-week soil incubation tests. As an aid to interpretation of the data, correlation coefficients between results other than the soil tests are shown in Table V.

TABLE IV

Correlation between the Seven-day Soil Incubation Tests and other Properties of Calcined Hoof and Horn Materials

	Tests	Correlation Coefficient	Significance
Soil test A	% water-soluble nitrogen ...	r=+0·699	P=0·001
,, ,, ...	% ammonia-nitrogen ...	+0·657	0·01
,, ,, ,, ...	% nitrogen by formol titration	+0·740	0·001
,, ,, ,, ...	Bulk density	+0·692	0·01
,, ,, ,, ...	% passing 60-mesh sieve ...	+0·487	0·05
,, ,, ,, ...	Soil test B	+0·945	0·001
Soil test B	% water-soluble nitrogen ...	+0·533	0·02
,, ,, ,, ...	% ammonia-nitrogen ...	+0·558	0·02
,, ,, ,, ...	% nitrogen by formol titration	+0·614	0·01
,, ,, ,, ...	Bulk density	+0·661	0·01
,, ,, ,, ...	% passing 60-mesh sieve ...	+0·438	0·1

TABLE V

Correlation between Various Chemical and Physical Tests made on 19 Samples of Calcined Hoof and Horn

	Tests	Correlation Coefficient	Significance
% water-soluble nitrogen ...	% ammonia-nitrogen ...	+0·858	0·001
,, ,, ...	% nitrogen by formol titration	+0·942	0·001
,, ,, ...	Bulk density	+0·500	0·05
,, ,, ...	% passing 60-mesh sieve ...	+0·754	0·001
% ammonia-nitrogen	% nitrogen by formol titration	+0·933	0·001
% ,, ...	Bulk density	+0·392	0·1
% nitrogen by formol titration	,, ,, ...	+0·503	0·05
% ,, ,, ,, ,,	% passing 60-mesh sieve ...	+0·698	0·001
Bulk density	% ,, ,, ,, ...	+0·517	0·05

As is frequently found in investigations of the mineralisation of nitrogen from organic materials, the determination of water-soluble nitrogen proved to be a reliable guide to the initial rates of decomposition of calcined hoof and horn samples in the soil. Analagous results with the nitrogenous constituents of bone meals have already been published.[2] Such correlations are to be expected in that, under suitable conditions and in absence of toxic constituents, soluble nitrogenous compounds are readily decomposed in the soil.

The results obtained by formol titration, used as a rapid test for soluble nitrogenous constituents, were in fact even more closely correlated with the seven-day soil tests than were the values for total water-soluble nitrogen. The ammonia determined by distillation of the samples with magnesia was also significantly correlated with the initial rates of mineralisation of nitrogen in the soil. All three chemical determinations related to the soluble nitrogenous constituents of the hoof and horn samples were themselves closely correlated, as shown in Table V. The values for ammonia by distillation and the nitrogen determined by formol titration were not only highly significantly correlated (r=0·933) but were also numerically similar, the mean values being 2·4 and 2·1 per cent. respectively of the total nitrogen. Whereas the total water-soluble nitrogen is a constituent of calcined hoof and horn materials of direct practical importance, the significance of the small amounts of ammonia requires a different interpretation. Numerically too small to influence the soil incubation tests directly to any appreciable extent, the presence of ammonia is doubtless related to the degree of decomposition of the original protein materials by heat-treament or by biological processes during storage.

As previously found for milled samples of raw hoof and horn, the simple physical determination of bulk density is significantly related to the initial rates of decomposition of the samples as shown by the seven-day soil incubation tests. If samples 35 and 37 are omitted, however, the actual range of bulk densities is relatively small, being from 0·57 to 0·69 g./c.c. Thus, despite the significance of the correlation coefficients obtained in this instance, the determination of bulk density as a guide to rates of decomposition in the soil is not to be recommended for calcined hoof and horn; it can, however, indicate samples in which heat-treatment has been insufficient to modify the fibrous nature of the raw material.

Despite milling through a 1-mm. grid before testing, the effect of particle size on the tests was not entirely eliminated. The percentages of the various samples passing a 60-mesh sieve were significantly correlated with the A series of seven-day soil tests at the 5 per cent. level, but just failed to attain this level for the B series. It is concluded that physical tests are of greater value for raw samples of hoof and horn than for the calcined materials. It is of interest, however, that a highly significant correlation at the 0·1 per cent. level was obtained between the percentage of the calcined materials passing the 60-mesh sieve and both the total water-soluble nitrogen and the formol titration. It thus appears that particle size had a greater effect on the preparation of aqueous extracts for analysis than on the decomposition of the samples in the soil.

Comparison of Raw and Calcined Hoof and Horn

Comparison of the data in Tables I and III shows that, for almost every test applied to both raw and calcined samples of hoof and horn, significant though not necessarily large differences can be demonstrated between the mean values in the two groups. Mean values for both raw and calcined hoof and horn are given in Table VI together with the level of statistical significance of differences between the two means where such differences are not self-evident.

TABLE VI

Mean Values for 22 Samples of Raw Hoof and Horn and 19 Samples of the Calcined Materials

Test	Mean Values		Significance of Difference between Means
	Raw	Calcined	
Total nitrogen	14·78%	14·03%	P=0·01
Water-soluble nitrogen*	1·5%	11·0%	
Sieved bulk density	0·284 g/c.c.	0·597 g/c.c.	
% passing 60-mesh sieve	37·3	74·2	
Soil test A (seven days)*	22·6%	28·6%	0·1 †
„ „ B „ „ *	26·5%	31·6%	0·05
„ „ C (10 weeks)*	73·7%	70·0%	0·01

* Expressed as a percentage of the total nitrogen of the samples

† Only just fails to attain significance at P=0·05.

The main effects of heat-treatment of the samples include increased bulk density of the milled products, greatly increased content of water-soluble nitrogen, and greater ease of milling. The initial rates of mineralisation of nitrogen are slightly increased by calcining, as shown by soil tests A and B, whereas the final "availability" of the samples is significantly but not greatly reduced (soil test C). The percentage of nitrogen in the calcined samples is slightly less than in the raw materials, suggesting slight losses of nitrogen either during calcining or as ammonia during subsequent storage. Direct comparisons of the mineralisation of nitrogen from raw and calcined samples of hoof and of horn have been made in three different soils, the results of one of these experiments being shown in Fig. 2. Both the calcined samples commenced to mineralise rapidly, whereas some lag occurred at first with the raw materials. This initial lag was particularly marked with raw horn, but rapid decomposition of both the raw samples soon followed. At the end of the tests hoof showed a higher percentage mineralisation than horn, and the raw samples surpassed the calcined materials in this respect. From the form of the curves the difficulty of reproducing the results of short-term incubation experiments in different batches of soil, as in the A and B series of soil tests, will be readily apparent. The differences in long-term availability of nitrogen found between the raw and calcined materials can possibly be attributed to greater stimulation of the soil population by the

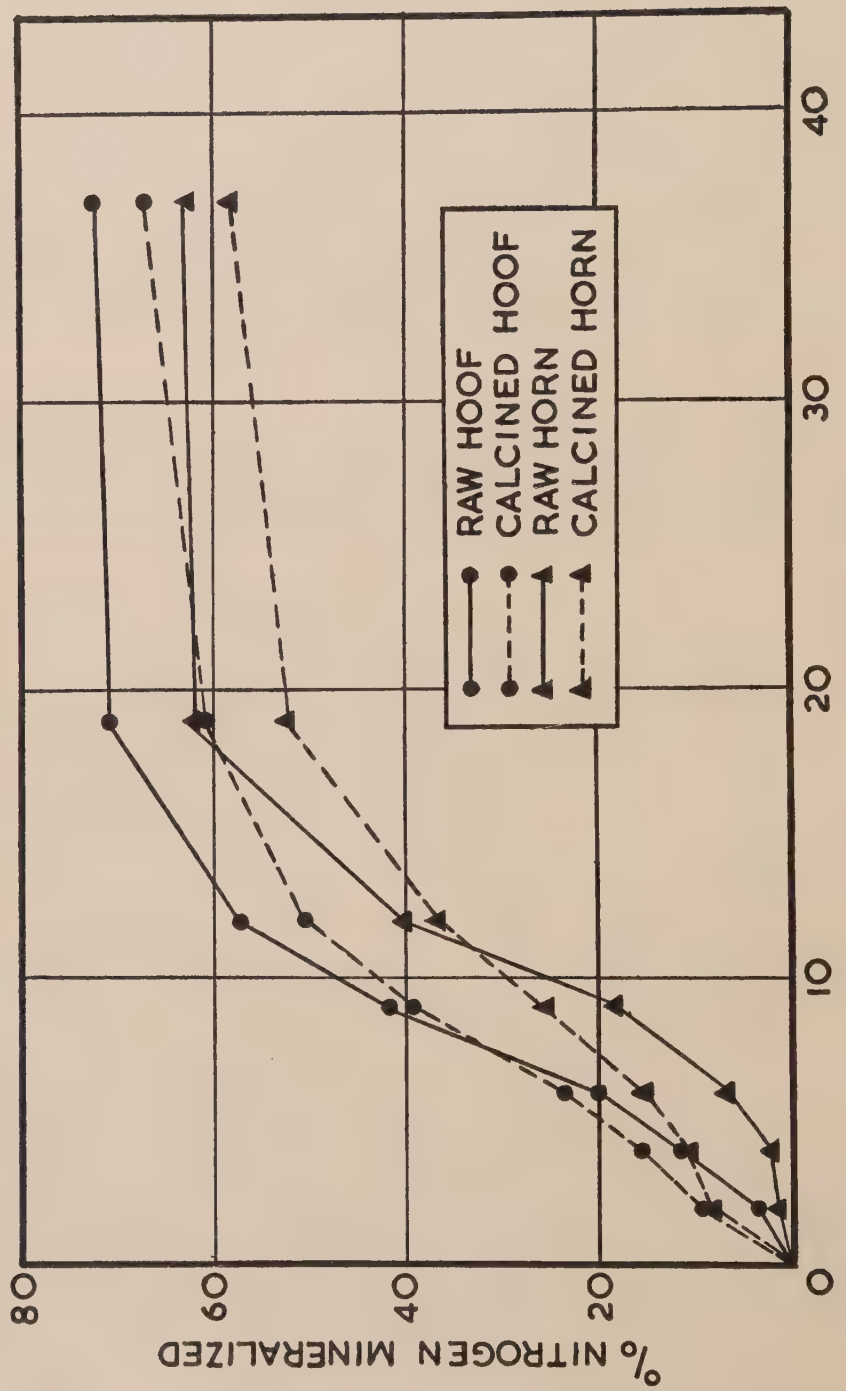

Fig. 2
Mineralisation of the nitrogen of raw and calcined hoof and horn in the soil.

latter, resulting in increased immobilisation of nitrogen. Despite the marked effect of heat-treatment upon the chemical and physical properties of the materials, the differences observed in the rates of mineralisation of nitrogen of the milled samples were relatively small.

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2. STEAM STERILIZATION STUDIES

By J. N. DAVIES

It has been shown previously that after steam sterilization high ammonia concentrations persist in glasshouse soils for several months, no conversion to nitrate occurring [1, 2]. Digging a steamed soil at regular intervals was found to accelerate the onset of nitrification, presumably as a result of incorporating surface infections into the main body of the soil.[2] These investigations have now been extended to a study of the ammonia and nitrate changes in a glasshouse soil which after steaming was flooded, base-dressed, and planted.

A length of tomato border in one of the experimental houses was divided into two, one half being steamed by the Hoddesdon pipe system in the late autumn, and the other half left unsteamed. At the time of steaming both steamed and unsteamed plots were divided into three by means of asbestos sheeting buried vertically in the soil to a depth of 15 ins. The three pairs of plots were then treated as follows: (*a*) left undisturbed apart from periodic watering to keep the moisture content at a reasonably constant level, (*b*) flooded with water 46 days after steaming at a rate equivalent to 50,000 gallons per acre, and base-dressed on the ninety-fifth day after steaming, and (*c*) treated similarly to (*b*) but in addition planted with tomatoes on the ninety-eighth day after steaming. The base dressing used in treatments (*b*) and (*c*) consisted of 4 ozs. per sq. yd. of each of the following: bone meal, hoof and horn, and sulphate of potash, with the addition of stable manure. The glasshouse was unheated for the first 88 days after steaming.

Analyses for ammonia and nitrate nitrogen in soil samples from the variously treated plots were made at intervals, and in addition an indication of the nitrifying capacity of the soil was obtained by incubating soil samples with added ammonium sulphate for six days at 23·5° C. Since, under the experimental conditions used the unsteamed soil was capable of nitrifying over 90 per cent. of the added nitrogen, similar results with steamed soil are regarded as indicating effective contamination with nitrifying organisms.

Ammonia and nitrate production and the capacity of the soil to nitrify ammonium sulphate were also studied in the propagating and potting mixtures in which the tomato plants were raised before being set out in the glasshouse border. The propagating mixture consisted of five parts of maiden loam to one part of stable manure steamed together in a small steam sterilizing unit. The steamed soil was stored under cover for three weeks and before use 6 ozs. each of lime and superphosphate were added to every 100 lbs. of soil. Seeds of tomato, variety Ailsa Craig, were sown in the resultant mixture and 100 per cent. germination was observed after seven days. Twenty-eight days after seed sowing the young seedlings were potted up in a mixture consisting of five parts of maiden soil to one part of stable manure steamed together, lime and superphosphate being added before use. The plants were finally set out in the border 24 days later.

Results for the steamed soil which was left undisturbed apart from occasional watering are shown in Fig. 1. After the usual initial rapid rise, ammonia nitrogen fluctuated between 30 and 45 p.p.m. up to the one-hundred-and-tenth day after steaming. Thereafter there was a slow fall in the ammonia concentration until on the two hundred and twenty-third day after steaming it was low, and similar to that in the corresponding unsteamed soil. Nitrates meanwhile showed a general tendency to increase, slowly at first and then more rapidly as the ammonia fell. In the unsteamed undisturbed soil ammonia concentrations were invariably low (Table I). Nitrates increased slowly at first when temperatures were low and more rapidly later when the glasshouse was heated.

The changes in the steamed soil which was flooded and base-dressed, and in that which in addition was planted with tomatoes, are shown in Figs. 2 and 3 respectively. Up to the time of the application of the base-dressing, ammonia concentrations were similar to those found in the steamed undisturbed plot. Flooding on the forty-sixth day after steaming washed some nitrate out of the soil, but apparently had little effect on the ammonia. The addition of nitrogenous fertilizers on the

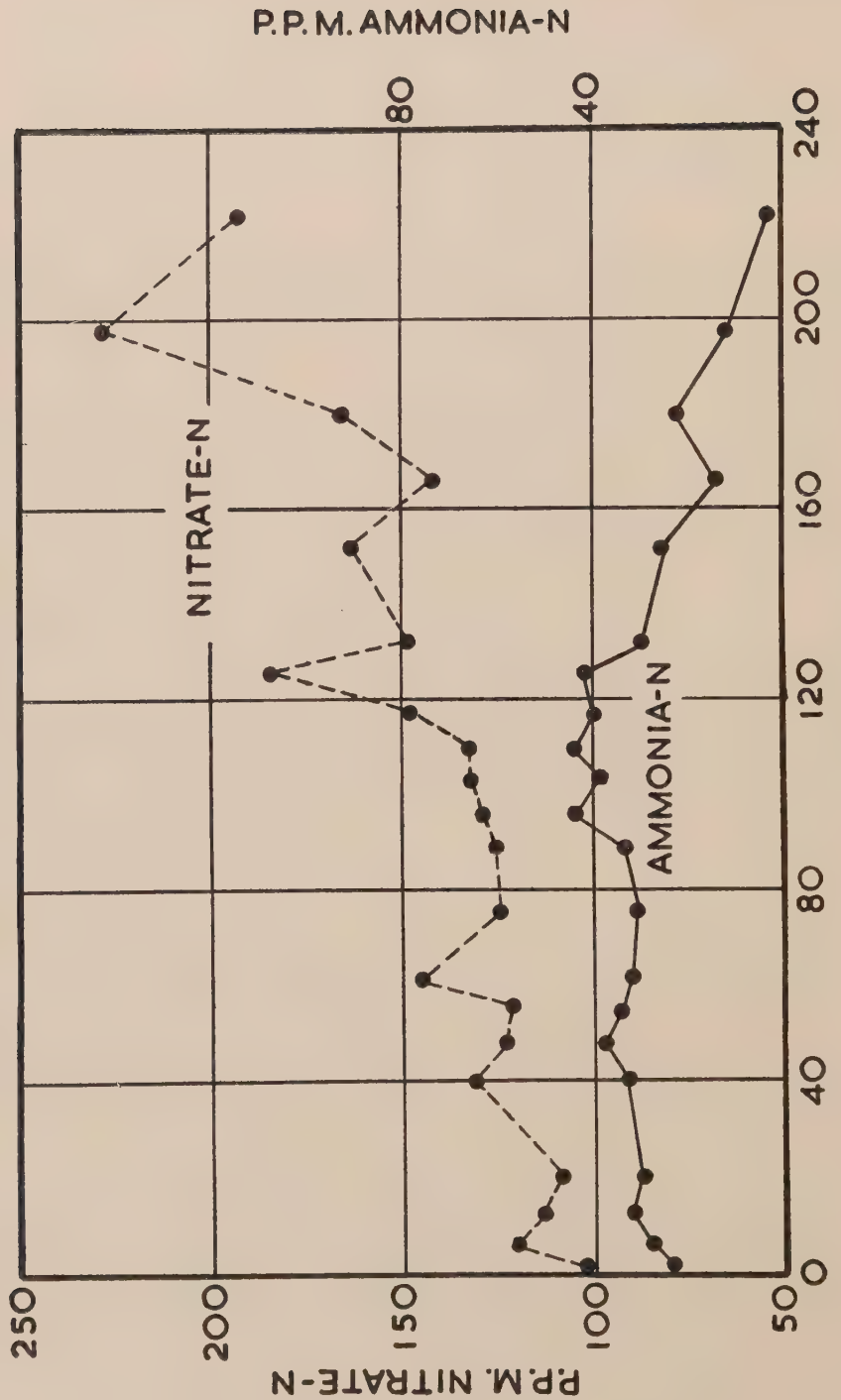

Fig. 1

Ammonia and nitrate production in steamed undisturbed soil.

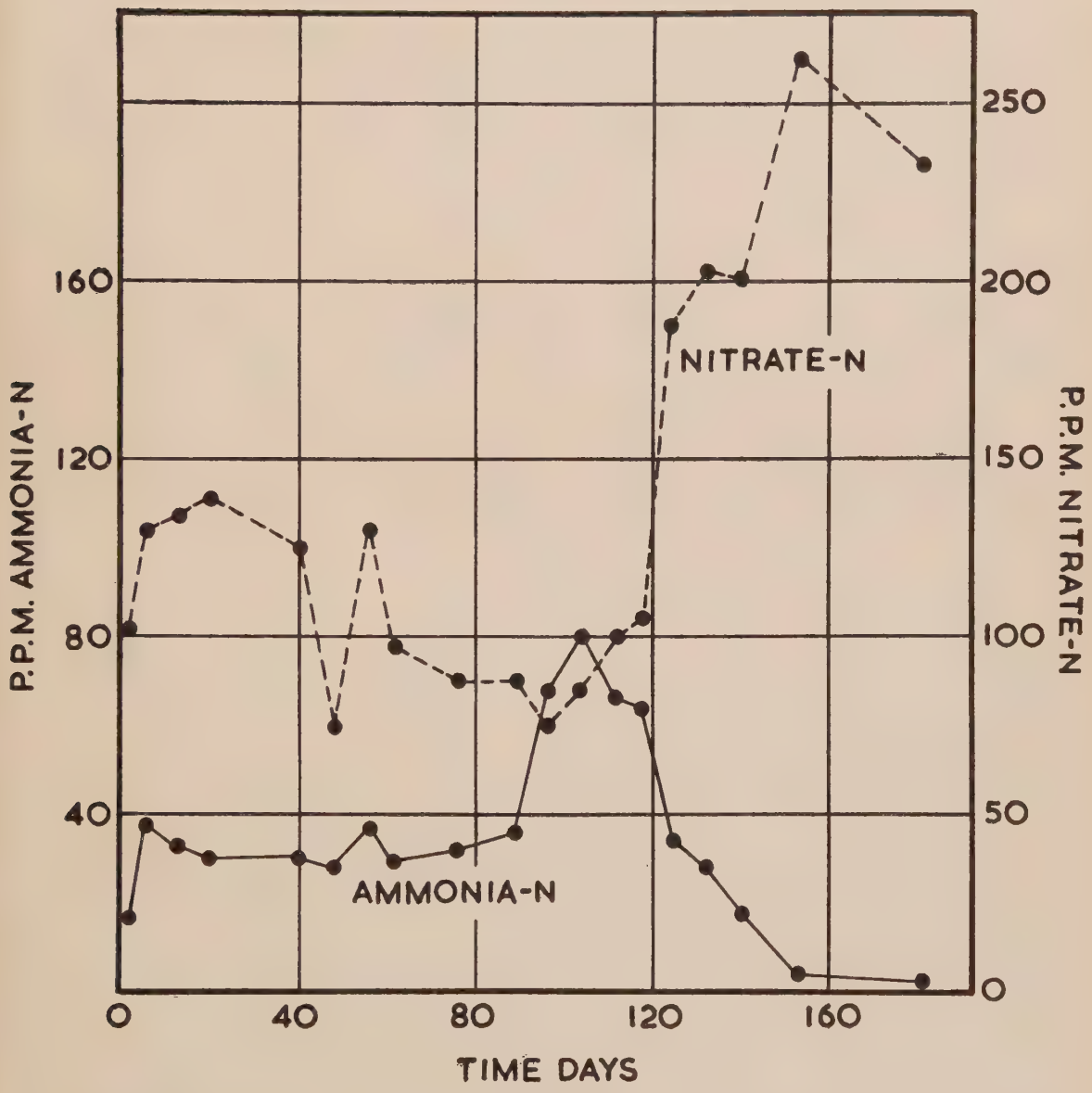

Fig. 2

Ammonia and nitrate production in steamed soil flooded with water on the forty-sixth day after steaming, and base-dressed on the ninety-fifth day.

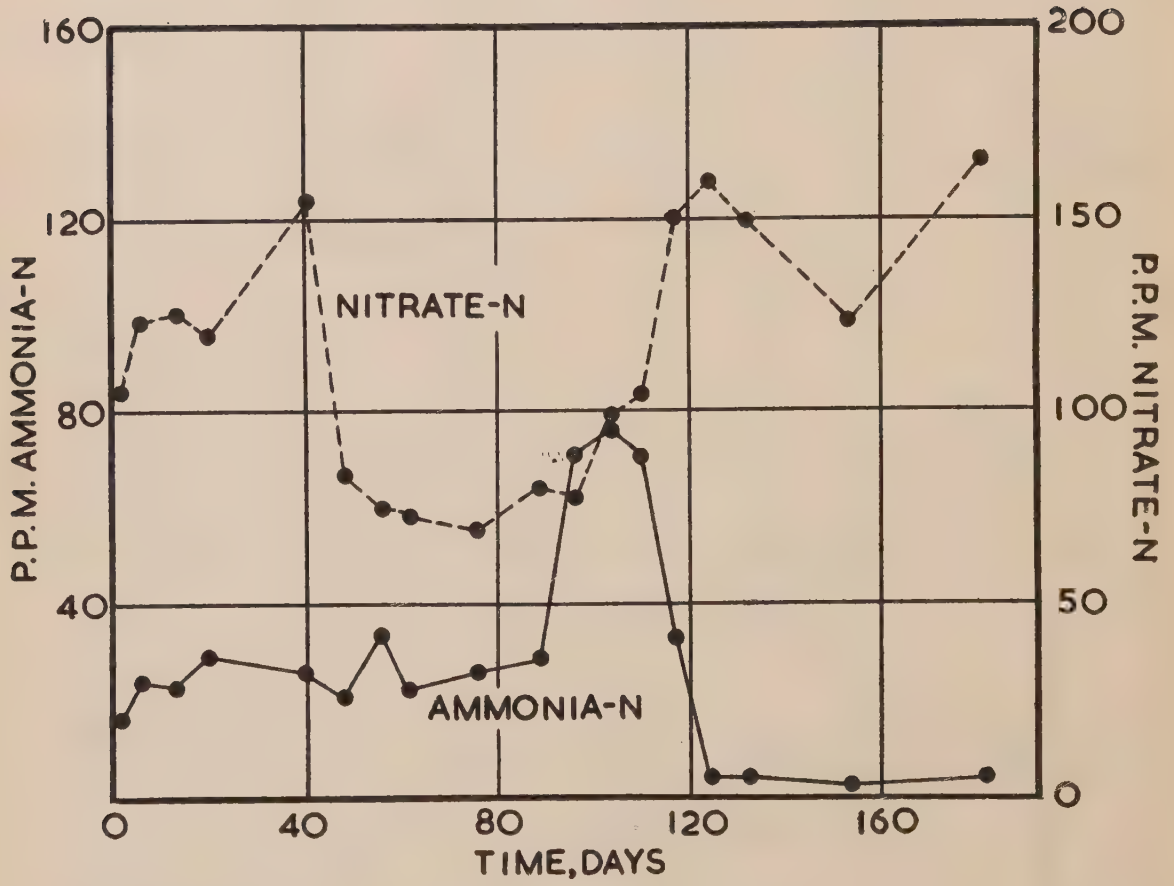

Fig. 3

Ammonia and nitrate production in steamed soil flooded with water on the forty-sixth day after steaming, base-dressed on the ninety-fifth day and planted with tomatoes on the ninety-eighth day.

ninety-fifth day, however, was followed by increased ammonia production in both plots, peak ammonia concentrations of approximately 80 p.p.m. being recorded on the one hundred and fourth day, i.e. nine days after the incorporation of the dressing. Within three weeks of the dressing being applied almost complete nitrification of the soil ammonia had taken place in the plot planted with tomatoes, whereas in the absence of the plants nitrification proceeded considerably more slowly, some eight or nine weeks elapsing before ammonia values similar to those in the unsteamed but base-dressed plot were observed.

In the unsteamed plots which were base-dressed, ammonia concentrations were low up to the time of the base-dressing, but after its application some ammonia production was observed (Table I). Within a fortnight, however, this had been nitrified with the formation of considerable amounts of nitrate. Subsequently nitrates increased in the unplanted plot, and slowly decreased in the planted plot.

TABLE I

Ammonia and Nitrate Nitrogen p.p.m. in the Unsteamed Plots*

Time in Days	Undisturbed		Base-dressed but not Planted		Base-dressed and Planted	
	NH_3-N	NO_3-N	NH_3-N	NO_3-N	NH_3-N	NO_3-N
1	1·8	20·2				
6	1·3	26·0				
13	2·0	38·2				
20	1·4	40·2				
41	1·3	30·8				
46	—	—	Flooded		Flooded	
48	1·6	65·9	1·5	24·3	0·8	20·8
55	1·4	60·8	0·8	36·0	0·6	28·7
62	1·4	79·4	2·6	41·6	1·4	37·4
76	1·7	55·9	2·0	40·4	1·8	37·3
90	3·4	77·9	3·2	43·6	3·1	39·2
95	—	—			Base-dressing	applied
97	6·5	51·4	28·6	37·9	33·2	44·5
98	—	—	—	—	Tomatoes	planted
104	2·4	52·8	15·9	62·4	10·5	111·2
111	4·6	64·1	7·3	96·7	3·8	122·5
125	4·3	69·9	2·6	96·7	2·0	108·4
153	4·1	104·9	2·2	139·2	2·2	82·6
181	3·0	133·5	3·0	195·9	2·5	34·3

* Composite samples from all three unsteamed plots were used to obtain the results shown for the first 41 days.

The results of the incubation experiments with ammonium sulphate are shown in Table II. Up to the ninety-fifth day after steaming little or no response to the added nitrogen after six days' incubation was observed in soil from any of the steamed plots. In addition, ammonia in the control samples did not disappear on incubation, but in general showed a tendency to increase as is shown in Table III. It therefore seems unlikely that during this period the steamed soil was contaminated with nitrifying organisms to any extent. After the base-dressing application, soil from the base-dressed but unplanted plot slowly increased in its response to the added nitrogen, until 37 days later on the one hundred and thirty-second day after steaming over 90 per cent. was recovered as nitrate after six days' incubation. Where tomatoes were planted the steamed soil was apparently much more rapidly contaminated with nitrifying organisms, and within a fortnight of planting over 89 per cent. of the added nitrogen was nitrified in the incubation period. Table III shows that considerable amounts of nitrate were formed in control samples from the base-dressed plots after the application of the dressing, while at the same time ammonia concentrations decreased.

Soil from the steamed but undisturbed plot was, in contrast, not capable of nitrifying 90 per cent. of the added nitrogen in six days until the one-hundred-and-sixty-seventh day after steaming. Nitrification in control samples from this plot did, however, begin earlier and after the one hundred and twenty-fifth day ammonia disappeared on incubation with the concomitant formation of nitrate.

Soil from the unsteamed plots regardless of treatment invariably nitrified between 85 and 100 per cent. of the added ammonium sulphate in six days.

From the foregoing it will be seen that disappearance of ammonia from the steamed soil which was left undisturbed was slow. Where the soil had received a base-dressing ammonia disappeared more rapidly, and where in addition tomatoes were planted ammonia fell to a low value within three weeks of planting. These results suggest that nitrifying organisms were introduced into the steamed soil with the base-dressing and also with the tomato plants.

TABLE II

% Recovery of added Ammonium Sulphate as Nitrate, after Six Days Incubation at 23·5° C., in soil from the Steamed Plots

Sampling Day	Neither Base-dressed or Planted	Base-dressed but not Planted	Base-dressed and Planted
1	<1·0	1·4	<1·0
6	<1·0	<1·0	<1·0
13	<1·0	<1·0	<1·0
20	<1·0	1·5	<1·0
41	1·3	4·4	1·3
48	<1·0	<1·0	<1·0
55	1·2	<1·0	<1·0
76	<1·0	<1·0	3·7
90	2·4	<1·0	1·6
97	—	<1·0	<1·0
104	<1·0	3·8	<1·0
111	4·2	22·7	89·4
118	<1·0	26·0	94·2
125	1·2	73·0	96·5
132	9·4	92·8	89·3
153	24·5	85·5	95·3
167	88·9	—	—
181	91·2	94·4	95·5
195	94·4	—	—
223	92·7	—	—

TABLE III

Changes in Ammonia and Nitrate Nitrogen (p.p.m.) in Control Samples taken from the Steamed Plots and Incubated for Six Days at 23·5° C. without the Addition of Ammonium Sulphate

Sampling Day	Neither Base-dressed or Planted		Base-dressed but not Planted		Base-dressed and Planted	
	NH_3-N	NO_3-N	NH_3-N	NO_3-N	NH_3-N	NO_3-N
1	+ 9·0	+ 2·5	+11·3	− 0·5	+ 7·3	− 1·1
6	+ 1·4	− 0·7	+ 2·7	+ 1·9	+ 1·7	+ 2·2
13	+ 1·4	− 0·3	+ 4·5	− 1·1	+ 2·8	− 0·1
20	+ 1·6	− 1·1	+ 4·2	− 1·2	+ 0·4	− 1·8
41	+ 3·4	+ 1·4	+ 2·0	+ 0·3	+ 1·4	+ 0·9
48	+ 0·7	− 4·4	+ 4·9	+ 1·3	− 1·9	+ 0·5
55	+ 2·8	+ 1·2	+ 5·5	+ 1·9	+ 5·5	+ 2·8
76	− 0·6	+ 1·8	+ 4·0	+ 0·6	+ 0·2	+ 0·8
90	− 2·7	+ 0·2	− 1·3	+ 0·7	− 3·6	+ 0·4
97	− 4·1	+ 5·5	+14·2	+18·5	+22·7	+ 5·7
104	+ 0·5	+ 2·7	−52·9	+63·7	−34·1	+50·3
111	−17·0	+ 5·0	−62·0	+76·8	−70·5	+84·7
118	− 5·7	− 1·0	−63·3	+70·4	−30·7	+37·7
125	−13·7	+18·8	−32·2	+49·1	− 4·9	+17·8
132	−24·9	+25·9	−26·8	+38·2	− 4·1	+24·0
153	−25·5	+28·8	− 3·9	+ 7·7	− 1·9	+ 6·3
167	−12·1	+23·0	—	—	—	—
181	−18·4	+22·0	− 2·0	+ 5·2	− 2·1	+ 4·5
195	−10·6	+12·0	—	—	—	—
223	− 2·0	+ 4·2	—	—	—	—

That the soil adhering to the roots of the young tomato plants at the time of planting out in the border was, in fact, actively nitrifying is shown by the results for the changes in the propagating

and potting mixtures. Ammonia and nitrate production in the propagating and potting soils are shown in Tables IV and V respectively, along with the nitrate recoveries obtained when soil samples were incubated with ammonium sulphate for six days. It will be seen from Table IV that ammonia in the propagating soil was high when the seeds were sown. The high nitrate recovery after incubation with the added nitrogen however suggests that at this time the soil was already contaminated with nitrifying organisms. This view is supported by the subsequent rapid disappearance of the soil ammonia with the formation of nitrate. Thus 27 days after sowing seed and one day before the young seedlings were transferred to pots the ammonia concentration was low, and the soil was apparently in an actively nitrifying condition.

TABLE IV

Ammonia and Nitrate Nitrogen in the Propagating Soil and the Percentage Recovery of added Nitrogen after Six Days' Incubation with added Ammonium Sulphate

Time in Days after Sowing of Seed	p.p.m. Ammonia-N	p.p.m. Nitrate-N	%Recovery of added N as Nitrate after Six Days' Incubation
0	90·4	85·0	93·5
6	92·4	93·7	97·3
14	19·8	145·7	90·9
27	7·5	79·8	92·7

When the seedlings were potted up, ammonia in the potting soil was high at 160 p.p.m. and less than 10 per cent. of the added nitrogen was recovered as nitrate after six days' incubation (Table V). Four days after potting, however, ammonia had begun to decrease and by the eleventh day it had to a large extent been nitrified. During the same period the nitrifying capacity of the soil increased rapidly, and by the twenty-first day over 90 per cent. of the added nitrogen was nitrified in six days. It will be seen from these results that the potting soil, although not markedly contaminated by nitrifying organisms when the seedlings were potted up, was actively nitrifying by the time the plants were set out in the glasshouse border. This is presumably the result of the introduction of the actively nitrifying propagating soil adhering to the roots of the seedlings.

TABLE V

Ammonia and Nitrate Nitrogen in the Potting Soil and the Percentage Recovery of added Nitrogen after Six Days' Incubation with added Ammonium Sulphate

Time in Days after Potting-up	p.p.m. Ammonia-N	p.p.m. Nitrate-N	% Recovery of added N as Nitrate after Six Days' Incubation
0	160·4	60·2	9·2
4	142·5	65·2	34·5
11	42·3	217·0	83·2
21	4·6	80·3	96·3

Discussion

In agreement with previously reported work [1, 2], high ammonia concentrations persisted for long periods in the steamed soil which was left undisturbed. About three months after steaming ammonia slowly began to decrease, but a further three or four months elapsed before it was completely nitrified. The soil was regularly watered in order to maintain the moisture content at about 18 per cent., and the surface soil was never allowed to dry out completely. It is therefore likely that, in addition to any contamination by nitrifying organisms arising from the subsoil, chance surface infections were able to multiply and spread downwards into the soil. It will be seen, however, that if this did in fact occur, the process was an extremely slow one. It is of interest in this connection that Warcup has recently shown that the recolonisation of steamed forest nursery soils by fungi is very slow, numbers being still very much lower than in the unsteamed soil even after 18 months.[3]

Where the soil was treated in accordance with normal glasshouse practice after steaming, the onset of nitrification was accelerated. Flooding the soil with water washed some nitrate out of the soil, but ammonia concentrations were little changed, and the treatment had no apparent effect on the nitrifying capacity of the soil as measured with ammonium sulphate. Digging in a base-dressing which included stable manure resulted in increased ammonia production, which was fairly rapidly followed by the nitrification of the soil ammonia. Walker and Thompson [4] have reported that the addition of farmyard manure to a soil immediately after steaming resulted in increased ammonia production in comparison to untreated steamed soil. They found however that nitrification began within three weeks of steaming whether farmyard manure had been added or not. This suggests that in their case some gross contamination of the soil occurred. Although these workers give no details of any changes in the soils in which the tomatoes were raised before planting out and draw no conclusions regarding the source of infection, it appears likely that it was introduced when tomatoes were planted 12 days after steaming. In the present investigation nitrification began much earlier where stable manure had been added than in its absence. When the base-dressing was incorporated into the steamed soil some surface infections may have been introduced into the main body of the soil, but it seems more probable that the stable manure was largely responsible for the contamination of the steamed soil with nitrifying organisms.

The most rapid nitrification in the steamed soil was observed where tomatoes were planted after the soil had been base-dressed. Within three weeks of planting the soil ammonia had almost completely disappeared. This suggests that the soil adhering to the tomato roots at the time of planting was contaminating the steamed soil in the glasshouse. Nitrifying organisms appear to have been present in the propagating soil when the seeds were sown, since at that time, although the ammonia was high, the soil was capable of nitrifying over 90 per cent. of added ammonium sulphate in six days (Table IV). Later the transplanting of the seedlings into the potting mixture was accompanied by the transfer of nitrifying organisms. Thus, the potting soil, which at first was apparently not contaminated to any large extent, rapidly became actively nitrifying (Table V). Subsequently the introduction of this soil into the glasshouse border proved to be an effective source of infection, and nitrification began there.

The foregoing conclusions are corroborated by the results for the nitrification experiments with ammonium sulphate. Before the base-dressing was applied the nitrifying capacity of the soil from all the steamed glasshouse plots was very low. The failure of the steamed soil to nitrify the added nitrogen does not necessarily imply the complete absence of nitrifying organisms; that may have been present, but other unfavourable conditions may have prevented their proliferation. In these experiments, however, the moisture content, pH and available calcium and phosphate levels all favoured nitrification. Moreover, during the first 90 days after steaming, the ammonia in the control samples from the steamed plots did not disappear on incubation, and no significant increases in nitrate were observed (Table II). In addition, similarly treated but unsteamed soil samples nitrified over 90 per cent. of the added nitrogen after six days' incubation. In the light of these results it therefore appears likely that the steamed soil in the glasshouse was not contaminated to any extent before the application of the base-dressing.

The nitrifying capacity of the steamed soil which was base-dressed but unplanted slowly increased after the dressing was applied, until some seven weeks later, approximately 90 per cent. of the added nitrogen was nitrified after six days' incubation. In the control incubated samples nitrification of the soil ammonia was observed earlier. These results taken in conjunction with those for the plot sampled *in situ* (Fig. 2) indicate that the soil that was base-dressed but unplanted became rapidly contaminated after the application of the dressing, but that some time elapsed before contamination became completely effective in the glasshouse.

Where the steamed soil was planted as well as base-dressed it was capable of nitrifying over 90 per cent. of the added nitrogen within a fortnight of planting, indicating that contamination was extremely rapid. In contrast, soil from the steamed undisturbed plot did not nitrify 90 per cent. of the added nitrogen until the one hundred and sixty-seventh day after steaming. Ammonia in the plot itself did not however completely disappear for a further six or seven weeks, indicating that like the steamed, base-dressed, but unplanted plot, contamination *in situ* was not followed by appreciable nitrification for some time.

The results of this investigation emphasise the need for care in handling steamed soil if contamination is not to result. If steamed soil can be readily infected with nitrifying organisms during the propagation of tomatoes, then it is likely that other injurious organisms may also be introduced.

Contamination risks should therefore be minimised by ensuring that steamed soil is adequately protected against infection during storage, and not allowed to come into contact with unsteamed soil or with unsterilized seed boxes or pots.

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3. THE EFFECTS OF SOME ACUTE MINERAL DEFICIENCIES ON PERPETUAL FLOWERING CARNATIONS

By J. H. L. MESSING

The visual symptoms of mineral deficiencies in young carnation plants were described in last year's Report. The main part of the 1951 experiment, in which plants were grown in complete nutrient solution until the time of opening of the first flower and differential treatments started in August 1951, was continued throughout 1952. The varieties grown were Spectrum and White Maytime.

The appearance of the deficiency symptoms was much delayed, and in most cases was not apparent until the spring of 1952, the main exception being that of boron deficiency. Using nutrient solutions prepared with distilled water, in absence of boron all the young buds were dead by the end of September, 1951. Demineralised water, however, contains enough boron to maintain the growth of carnations for a considerable period; when used in place of distilled water the deficiency symptoms were very slight, and tended to disappear in winter even in plants so treated since May, 1951. Omission of nitrogen was the only other treatment to which a definite reaction was noted in the autumn and winter. Poor growth and somewhat erratic symptoms were observed in the absence of calcium, and slight shortening of the internodes and stiffening of the stems in absence of sulphur. The omission of phosphorus, potassium, and magnesium produced no symptoms of deficiencies until the spring, while the omission of iron, manganese, and zinc failed to show any definite symptoms throughout the entire experiment.

(a) No Nitrogen

Slow and extremely hard growth resulted from the omission of this element, the internodes failing to elongate. This effect was more pronounced than in young plants grown during the summer. The old leaves died off quite slowly, suggesting only slow re-utilisation of nitrogen to meet the small requirement of winter growth. This conclusion is further substantiated by the observation that in April some limited growth took place. evidently at the expense of the now rapidly dying old foliage. At this stage a few plants of both varieties flowered, the blooms being small but otherwise normal. The flowering stems were short, and the leaves small and pale green. The regular dying back of the old leaves from the tips and the effect on the production of side shoots were as described for young plants in the 1951 Annual Report.

At the beginning of January Spectrum developed symptoms which might be described as "curly tip." The tips of the young leaves failed to separate and the continuing growth caused a characteristic curvature. Somewhat similar symptoms were later observed in the no-sulphur treatments, as will be described under that heading. Apart from one or two very weak winter shoots, however, these symptoms were not observed in any of the other eight treatments at any time of the year. Similar symptoms are known to occur under commercial conditions during winter and early spring, these being generally attributed to poor light. Some varieties were more susceptible than others. Thus on the Experimental Station nursery Red Pimpernel and William Sim were particularly affected this year whereas Maytime (pink) and White Maytime did not show it.

As a further test of the connection between nitrogen deficiency and the "curly tip" symptoms nitrogen was withheld from other plants at different stages of growth and time of year. The characteristic symptoms appeared in every case, irrespective of season, though the effect was most pronounced in winter. Every shoot of Spectrum was affected; William Sim was also grown and reacted similarly. There is thus no doubt that lack of nitrogen was responsible for the symptoms observed in the present experiment. Observations elsewhere suggest that plants grown under less favourable conditions may develop these symptoms, despite an adequate supply of nitrogen, when

growth is adversely affected by other factors such as poor light and low temperatures. It was noted, however, that the lower the nitrogen level the earlier was the appearance of the symptoms.

As previously stated, not all varieties are equally susceptible to "curly tip." Thus in the present experiment White Maytime, though showing some tendency for the younger leaves to stick together, only rarely developed a slight curling of the leaves. This variety, together with Maytime (pink) and a number of others, was free from it when grown commercially. It appears that these varietal differences are linked with length and texture of leaf, varieties normally having long and relatively soft leaves being the more affected.

(b) No Phosphorus

Experiments were continued with both the "early" and "late" series of the 1951 programme. As stated in the previous Report, there appear to be no characteristic visual symptoms by which phosphorus deficiency can be easily identified in carnations. In the case of the plants of the "early" series from which phosphorus was withheld since May 1951, growth was very slow. The young shoots had short internodes, and only a few sideshoots were produced. At this stage the symptoms were somewhat similar to those of nitrogen deficiency, the main difference being one of colour. Thus the phosphorus-deficient plants remained dark green, with the old dead leaves of a dark brown colour in contrast to the light yellow-brown associated with nitrogen deficiency. Further differences were noted in the manner of dying off of the old leaves. In the case of nitrogen deficiency tip scorch developed, followed by regular dying back of each leaf across the whole width of the blade, whereas in phosphorus deficiency irregular chlorotic patches developed at any part of the leaf, followed by a spreading necrosis.

The plants of the "late" series, well established on complete nutrient solution, were very slow to show symptoms and reacted only slightly. The main features were the dying off of the older leaves and reduced flower production.

(c) No Sulphur

As explained in last year's Report, the nutrient solution used in this treatment actually contained 0·05 p.p.m. sulphur, this being supplied in the trace element solution. Growth of the plants was slow, and stiffness of the stems was noted at an early stage. The symptoms described in 1951 were again observed, and no part of the plant died. In addition to these effects the symptoms of "curly tip" were observed with Spectrum; the young leaves were stiff and tightly rolled so that their separation was delayed, continued growth resulting in a characteristic curvature of the leaves. Their appearance was thus somewhat similar to that already described for nitrogen deficiency, but when sulphur was deficient the leaves were markedly stiffer.

Early in May it was decided to modify the nutrient solutions so as to avoid even the trace of sulphur referred to above. As a result of this change the deficiency symptoms became more acute, and both the development of buds and the elongation of internodes ceased. At the top of each young shoot a tuft of very stiff leaves was formed, the lowest leaves of which developed white scars and irregular discoloured patches, usually close to the base of the leaves; in some cases these scars were also observed on the stem just below the tufts of leaves. Wilting and death of the affected leaves followed. On shoots with flower buds already formed similar scars appeared on the uppermost leaves, causing their distortion; the buds died without opening. With White Maytime curling of the leaves on the flower stems made a distinctive feature at this stage, and many of the blooms were distorted. In the case of Spectrum the blooms were invariably a lighter red than on the control plants, and variegated with white.

(d) No Potassium

There was no noticeable reaction to this treatment until April, 1952. The symptoms then appeared suddenly, and with White Maytime followed exactly the same pattern as in the young plants of 1951. Spectrum was again slower to react, and reproduced the 1951 symptoms with the exception of an occasional leaf in which dying back from the initial tip scorch was preceded by the appearance of a few necrotic spots. Many of the shoots died completely but, unlike the younger plants of the preceding season, a certain amount of new growth was produced, probably involving re-utilisation of potassium. The new stems were weak, with short internodes; the leaf blades were narrow and long, especially with Spectrum. White Maytime was more affected by potassium deficiency, and little secondary growth took place. In both varieties the flowers formed after the onset of the first symptoms of deficiency were of poor quality. At a later stage the early death of the calyx was noted, necrosis appearing first on the upper margins.

(e) No Magnesium

Here again the appearance of the first symptoms was delayed until April, 1952, and only slightly preceded those of potassium deficiency. Chlorosis appeared on the middle leaves and spread rapidly up and down the plant, becoming extremely acute. The second phase of magnesium deficiency observed on the young plants in 1951, namely the development of bands of necrotic tissue near the base of the leaves, was less prominent in 1952. The death of most of the old leaves and even of entire shoots was followed in Spectrum by resumed growth, probably again involving re-utilisation of the deficient element. After a time the internodes became short and the leaves long and narrow, the symptoms being even more marked than in the case of potassium deficiency. The leaves were of a light green colour, characteristic of this deficiency. White Maytime produced only limited secondary growth; the more advanced flower buds opened rapidly and death of the plant soon followed. It may be noted that the effects of acute potassium and magnesium deficiencies became somewhat similar in the later stages, including death of the calyx as described under no potassium.

(f) No Calcium

Growth and production of flowers was adversely affected throughout the autumn and winter, but the symptoms were erratic and ill-defined. Early in March definite symptoms appeared and all White Maytime plants died in the first half of May. The symptoms were the same as described for young plants in 1951, but the differences between varieties in resisting the deficiency were more marked on this occasion. Tip scorch of the young leaves and death of the growing points was followed in White Maytime by widespread dying off of the older leaves; the colour of the foliage was not noticeably affected in this variety. Axiliary buds became active, but the young shoots died after developing one or two pairs of leaves. Quite suddenly the remaining leaves shrivelled, and the entire plants were dead within a few days. Although tip scorch and death of the growing points occurred at approximately the same time for both varieties, considerable differences were found in the later stages. Thus with Spectrum dying back from the leaf tips was slower, and practically no death of old foliage occurred. The entire plants acquired an unhealthy dark green colour, and axiliary buds became active. The resulting shoots were weak, and at an early stage developed the same symptoms as were earlier observed on the main shoots. Slow dying back of the whole plant followed.

(g) No Boron

The symptoms of this deficiency were described in detail in the 1951 Report for both the "early" and "late" series of the experiment. As previously stated, the use of demineralised water in place of distilled water in the nutrient solutions gave rise in the first year to only slight deficiency symptoms which tended to disappear in winter. In the second year, however, the traces of boron present in demineralised water proved insufficient to maintain the larger plants, and more marked deficiency symptoms resulted. A description of these symptoms is given for both varieties for comparison with the results already reported using distilled water.

In White Maytime an early indication of boron deficiency was given by the abundant growth of side shoots. Growth was slow, the stems being weak and limp. The leaves were small and pale green, similar in colour to those in the no nitrogen treatment but not as dry in texture. There was no sign of the stiffness of stem or thick leathery leaves normally associated with lack of boron. In May the older leaves started to die at an abnormal rate; some three weeks later the death of young flower buds was observed, and general wilting and death soon followed.

In Spectrum the symptoms resembled those in the distilled water series, differing mainly in severity and sequence. Bushy growth was first noted, followed by shortening of the internodes, death of some of the buds and adverse effects on the blooms. The youngest leaves developed the same symptoms as described in 1951 for the distilled water series. These symptoms eventually diminished, however, and growth subsequently improved. With such fluctuations the plants survived till autumn, when they still further recovered.

The more severe symptoms noted with White Maytime suggest a general starvation not only of boron but of other elements. Such an effect could be caused by an adverse effect of boron deficiency on the roots and conductive tissue; this view is supported by the sudden death of the entire plant. Although it should not necessarily be concluded that Spectrum has a lower requirement for boron than has White Maytime, it does appear that Spectrum is better adapted to survive at low concentrations of this element.

(h) No Manganese, Iron and Zinc

No visual symptoms of deficiency of any of these three elements were observed in the present experiment.

Using the same technique, sand, and grade of chemicals acute symptoms of manganese deficiency were earlier produced in chrysanthemums and tomatoes. Zinc deficiency symptoms were also studied for tomatoes, and were easily produced in the summer months. Iron deficiency has, however, always been difficult to demonstrate under our conditions, and in the case of chrysanthemums only mild symptoms were obtained. It is concluded that the requirements of carnations for these three elements, especially for manganese, are in all probability very low. To illustrate further the lack of effect when these elements were omitted from the nutrient solutions, comparative data are given in Table I, including mean stem length, mean diameter of flowers, the number of flowers per plant, and percentage of "splits."

TABLE I

Variety	Treatment	Average Number of Blooms per Plant	% of Splits	Average Length of Stem in Inches	Average Diameter of Bloom in Inches
White Maytime ...	Control ...	34·0	26·5	22·8	2·89
	No manganese	32·5	28·2	23·5	2·92
	No iron ...	26·5	48·0	23·7	2·87
	No zinc ...	29·0	37·0	22·7	2·79
Spectrum	Control ...	30·0	21·3	24·1	2·85
	No manganese	27·0	20·5	23·5	2·81
	No iron ...	25·0	41·0	24·0	2·94
	No zinc ...	28·5	14·1	23·4	2·75

From these results it will be seen that, apart from the lack of definite deficiency symptoms, there was little difference in general growth between the various treatments and control. There is, however, some evidence that when iron was omitted the number of blooms was reduced and the percentage of "splits" increased. The high percentage of "splits" observed with White Maytime on omission of zinc may well be due to wilt disease as, although plants showing definite symptoms of wilt were excluded, its presence in the remaining plants was suspected; the observations suggest that infected plants "split" badly.

4. THE EFFECT OF SULPHUR ON THE pH AND CARBONATE CONTENT OF A TOMATO SOIL

By D. M. MASSEY

Experiments were commenced in 1943[1] to study the effect of sulphur on the pH and carbonate content of a tomato soil. Sulphur was applied to one plot at the rate of 4 ozs. per sq. yd., to a second plot at 2 ozs. per sq. yd., and omitted from a control plot. From this preliminary work, continued in 1944,[2] it was concluded that these comparatively small dressings of sulphur had little permanent effect on the soil pH. In 1945[3] a heavier dressing of 1 lb. sulphur per sq. yd. was applied to one plot, and for the first time an appreciable reduction in carbonate content of the soil was recorded. The pH of the treated plot fell from 7·49 in January to 6·60 in May, but by the end of the year it had risen again to 7·14. In order to see how far the lower values for carbonate would persist in the soil neither lime nor sulphur was added in 1946.[4] In the course of the year the pH fluctuated considerably, but the value of 7·17 found in December was similar to that obtained at the beginning of the year. It was concluded that the heavy dressing of sulphur had in fact effected a permanent reduction in lime content. The application of 1 lb. sulphur per sq. yd. was resumed in 1947, and continued until the end of the experiment in 1952; the pH of soil samples taken from this plot from 1945 to 1952 has been plotted against date of sampling in Fig. 1. With the exception of 1946, when no sulphur was applied, the sequence of changes in pH within any one year follows a general pattern despite considerable fluctuations. In each case the application of sulphur was made at the end of February or the beginning of March, after which the pH of the soil decreased as a result of biological transformation. Before the end of each year the pH tended to rise again, presumably by

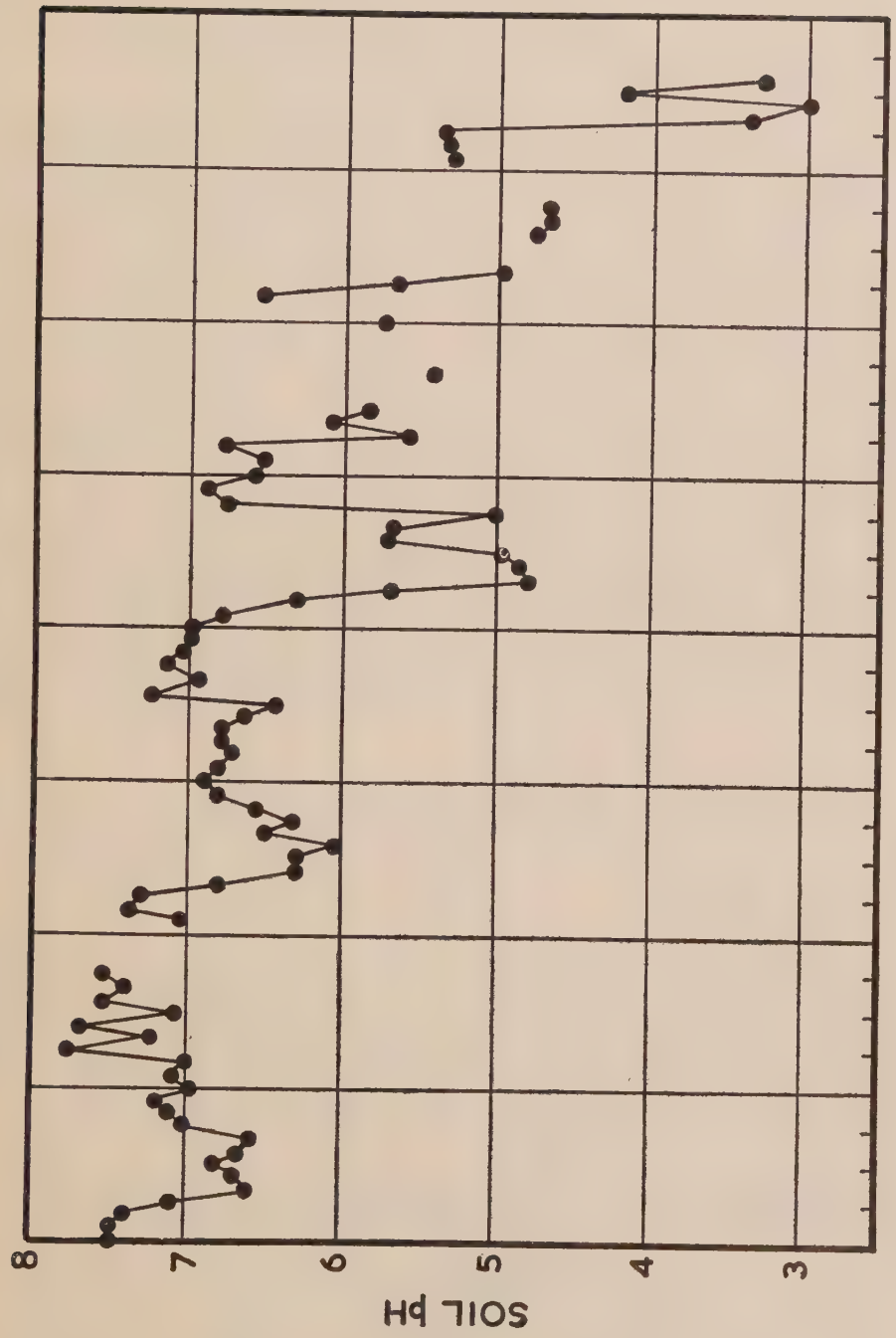

Fig. 1
The effect of sulphur on the pH of a tomato soil.

a slow reaction between the acid products formed from the added sulphur and the carbonate of the soil. Until 1949 the pH tended to fluctuate around neutrality, but following the sulphur treatment in that year a very marked decrease in pH occurred, values below pH 5 being recorded in May, June, and July. The pH soon increased again, and it was not until 1951 that values below pH 5 were again recorded. By this time, however, the buffering effect of the soil was much reduced, and following the application of sulphur in 1952 the pH fell to extremely low levels, a value of 3·0 being recorded in June, 1952. As expected at such low pH values, the tomato plants suffered badly, only 61 out of 120 plants surviving to the end of the season. In one case soil removed from the roots of a dying plant gave a pH value as low as 2·37.

The sequence of events throughout the experiment may thus be divided roughly into two stages. In the first stage, from 1945 to the end of 1948, the carbonate content of the soil was high and the pH fluctuated in the region of 7, being within the limits 6–8. In the second stage, from 1949 to 1952, the buffering effect of the soil was less marked and, despite fluctuations, the pH fell more sharply until extreme acidity brought the experiment to an end. The close relationship between carbonate (expressed as calcium carbonate) and pH is shown in Fig. 2. As long as the carbonate content of the soil exceeded a value of approximately 0·8 per cent. the pH rarely fell outside the range of 6·5 to 7·5. At lower carbonate values, however, more marked changes in the pH occurred, as shown in the later stages of the experiment. By August 1952 no carbonate could be detected in the soil. As previously noted, the pH values recorded in Fig. 1 show considerable fluctuations. Apart from the obvious sampling difficulties, growth of the crop and application of top-dressings, one factor which tended to obscure the general trend of events was the disturbance caused by steam sterilization. The laying of pipes for steaming by the Hoddesdon method at the end of the season inevitably disturbed the soil, and in 1946 and 1948 deep steaming was carried out as a control for eelworm. As a result of subsoil being brought up by these operations, the carbonate content of the top soil at the end of 1946 was considerably higher than at the start of the experiment.

The low pH values attained in 1952 made it necessary to discontinue the application of sulphur, but the opportunity was taken to investigate several other properties of the soil under conditions of extreme acidity. Data were also obtained for the control plot and for a further plot used in the preliminary experiments and subsequently treated with sulphur at the rate of ½ lb. per sq. yd. since 1949. One effect of the extremely acid conditions resulting from the heavy application of sulphur was a marked inhibition of nitrification. Values for ammonia and nitrate in soil samples taken in September 1951 are given in Table I.

TABLE I

Ammonia and Nitrate-Nitrogen (p.p.m.) in Soils treated with different Levels of Sulphur

	Control Soil	*½ lb. Sulphur per sq. yd.*	*1 lb. Sulphur per sq. yd.*
Ammonia (p.p.m. NH_3–N)	6·7	7·3	75
Nitrate (p.p.m. NO_3–N)	181	93	89

The low concentrations of ammonia in the control plot and in that receiving ½ lb. sulphur are quite normal for glasshouse soils, but the high ammonia value in the soil treated with 1 lb. sulphur per sq. yd. indicates that nitrification was markedly inhibited under these conditions.

Treatment with sulphur produced a high content of soluble salts in the soil, of which a large proportion consisted of calcium and sulphate. The total solids present, expressed in p.p.m., are given in Table II for the conventional 1 : 5 soil/water extraction ratio and for three other ratios.

TABLE II

The Total Solids (p.p.m.) extracted at Soil/Water Ratios of 1 : 5 to 1 : 20 from Soils treated with different Levels of Sulphur

Soil/Water Ratio	*Total Solids, p.p.m.*		
	Control Soil	*½ lb. Sulphur*	*1 lb. Sulphur*
1 : 5	8,410	14,580	18,080
1 : 10	9,550	17,890	33,380
1 : 15	9,990	18,810	40,050
1 : 20	10,670	21,370	43,080

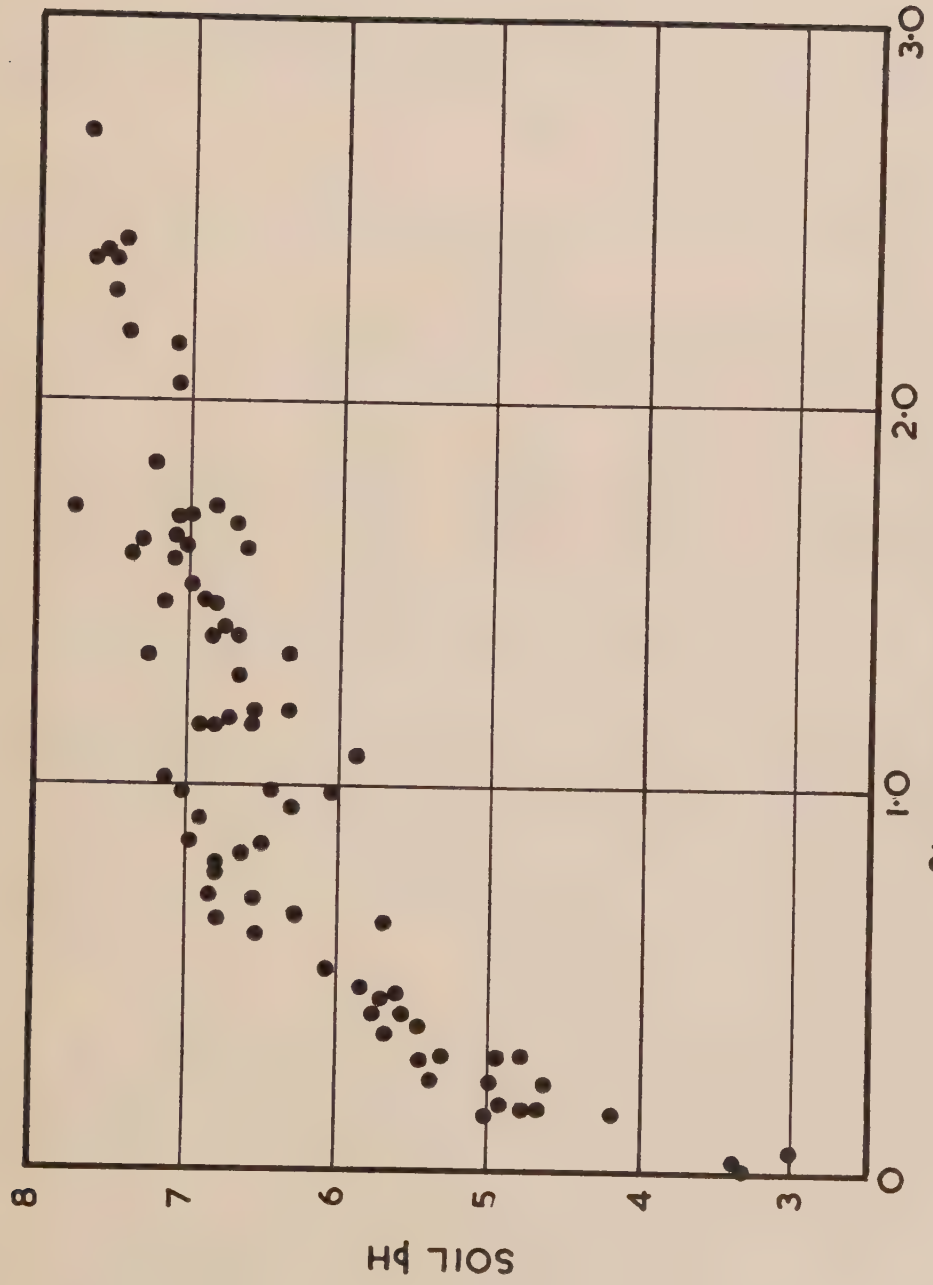

Fig. 2

The relationship between pH and carbonate in a tomato soil treated with sulphur.

The value of 43,080 p.p.m. total solids extracted from the soil receiving the higher application of sulphur, using a soil/water ratio of 1 : 20, included 22,900 p.p.m. sulphate and 10,200 p.p.m. calcium. It thus appears that a large proportion of the soluble matter consisted of calcium sulphate, produced by oxidation of sulphur and neutralisation by the calcium carbonate originally present in the soil. Calcium sulphate is somewhat sparingly soluble in water, thus accounting for the marked effect of soil/water ratio upon the extraction of soluble salts from the treated soils.

As described in the Annual Report for 1950[5] and 1951,[6] the application of sulphur at the rate of 4 ozs. per sq. yd. has been used to correct manganese deficiency in glasshouse roses. It was therefore considered of interest to examine the levels of manganese in the present series of tomato soils treated with sulphur. The method used was that of Sherman, McHargue and Hodgkiss,[7] in which three categories of soil manganese are estimated, these being

(1) Water-soluble manganese;
(2) Exchangeable manganese;
(3) Easily reducible manganese.

The results of these determinations, made in November 1952, are given in Table III.

TABLE III

WATER-SOLUBLE, EXCHANGEABLE AND EASILY REDUCIBLE MANGANESE IN SOILS TREATED WITH DIFFERENT LEVELS OF SULPHUR

	p.p.m. manganese.				
	Water-soluble	*Exchangeable*	*Easily Reducible*	*Sum*	% $CaCO_3$
Control	0·8	2·1	99·7	102·6	1·22
½ lb. sulphur per sq. yd. ...	9·0	12·8	92·2	114·0	0·38
1 „ „ „ „ „ ...	73·8	11·8	38·4	124·0	0

The control plot thus contained only traces of water-soluble and exchangeable manganese, but a considerable amount of easily reducible manganese was present. The plot treated with ½ lb. sulphur per sq. yd. contained a higher concentration of manganese in both the water-soluble and exchangeable categories. At the highest level of added sulphur the concentration of water-soluble manganese was particularly high, and the amount of easily reducible manganese correspondingly reduced.

It will be seen from the foregoing that repeated applications of sulphur to a tomato soil eventually produced a condition of extreme acidity; high concentrations of soluble salts accumulated and the soil became markedly unsuitable for plant growth. As long as carbonates were present in the soil in appreciable quantities the permanent effect of sulphur treatment on soil pH was relatively slight. As the carbonate content was further reduced, however, a marked fall in pH occurred.

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APPENDIX "B"

MANURIAL TREATMENT IN TOMATO EXPERIMENTS
(Except plots in Appendix C)

			BASE TREATMENT						TOP DRESSING							
House	Plot	Sterilization	Lime	Stable Manure	Hoof and Horn	Bone Meal	Sulphate of Potash	Sulphate of Ammonia	Sulphate of Potash with first Watering	Balanced Mixture	Dried Blood Mixture	Sulphate of Ammonia	Superphosphate	Sulphate of Potash	Dried Blood	Nutrient Feeding by Solufeeder
1		Steam	1 ton per acre				10 cwts. per acre		5 cwts. per acre	9 applications	None					
3	1	Formaldehyde	1 ton per acre	15 tons per acre	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts. per acre	8 applications						
	2	,,	,,	,,	,,	,,	,,		,,	,,						
	3	,,	,,	,,	,,	,,	,,		,,	,,						
	4	,,	,,	,,	,,	,,	,,		,,	,,						
	5	,,	,,	,,	,,	,,	,,		,,	,,						
	6	,,	,,	,,	,,	,,	,,		,,	,,						
	7	,,	,,	,,	,,	,,	,,		,,	,,						
	8	,,	,,	,,	,,	,,	,,		,,	,,						
4	4	D.D.	1 ton per acre	15 tons per acre	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts.	8 applications	None					
	5	Chloropicrin	,,	,,	,,	,,	,,		,,	,,	,,					
	6	,,														
	7	D.D.	,,	,,	,,	,,	,,		,,	,,	,,					
	8	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	9	,,	,,	,,	,,	,,	,,		,,	,,	,,					
5	1	Formaldehyde	1 ton per acre	15 tons per acre	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts. per acre	7 applications	None	1 application				
	2	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	3	,,	None	,,	,,	,,	,,		,,	,,	,,					
	4	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	5	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	6	,,	1 ton per acre	,,	,,	,,	,,		,,	Drip-watering	Liquid feeding					
7	–	Formaldehyde	1 ton per acre	15 tons per acre	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts. per acre	6 applications	2 applications	1 application				
8	1	Steam	1 ton per acre	15 tons per acre	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts.	6 applications	1 application	1 application				
	4															

	7	"	"	"	"	"	"		"	"	"					
	2	D.D.	"	"	"	"	"		"	"	"					
	3		"	"	"	"	"		"	"	"					
	5	"	"	"	"	"	"		"	"	"					
	8	"	"	"	"	"	"		"	"	"					
		"	"	"	"	"	"		"	"	"					
9	1	Steam per acre	1 ton	None	None	None	10 cwts. per acre		5 cwts. per acre	6 applications	1 application	1 application				
	5	"	"	"	"	"	"		"	"	"	"				
	9	"	"	"	"	"	"		"	"	"	"				
	13	"	"	"	"	"	"		"	"	"	"				
	2	Untreated	"	15 tons per acre	10 cwts. per acre	10 cwts. per acre	"		"	"	"	"				
	7	"	"	"	"	"	"		"	"	"	"				
	11	"	"	"	"	"	"		"	"	"	"				
	14	"	"	"	"	"	"		"	"	"	"				
	3	Formal-dehyde	"	"	"	"	"		"	"	"	"				
	6	"	"	"	"	"	"		"	"	"	"				
	10	"	"	"	"	"	"		"	"	"	"				
	15	"	"	"	"	"	"		"	"	"	"				
	4	Chloro-picrin	"	"	"	"	"		"	"	"	"				
	8	"	"	"	"	"	"		"	"	"	"				
	12	"	"	"	"	"	"		"	"	"	"				
	16	"	"	"	"	"	"		"	"	"	"				
10		Formal-dehyde	1 ton per acre	15 tons per acre	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts. per acre	6 applications	1 application	1 application				
11	1	Steam	1 ton per acre	None	None	None	10 cwts. per acre	None	5 cwts. per acre	6 applications	2 applications					
	2	"	"	"	"	"	"	"	"	"	"					
	3	"	None	"	"	"	"	"	"	"	"					
	4	"	"	"	"	"	"	"	"	"	"					
12	1	Steam	1 ton per acre	None	None	None	10 cwts. per acre	None	5 cwts. per acre	None	2½ cwts. per acre		None	2½ cwts. per acre		
	2	"	"	"	"	"	"	"	"	"	"		"	"		
	3	"	None	"	"	"	"	"	"	"	"		"	"		
	4	"	"	"	"	"	"	"	"	"	"		"	"		
Rose House		Steam	1 ton per acre	None	None	None	10 cwts. per acre		5 cwts. per acre	7 applications						

APPENDIX "C"

MANURES APPLIED IN PLOTS 1–3 AND 8–10 IN TOMATO HOUSE 4

Plot	Title	Base Manure in Lbs. per sq. yds.				*Top Dressing in Lbs. per sq. yds.		
		Lime	Stable Manure	Super-phos-phate	Sulphate of Potash	Super-phos-phate	Sulphate of Ammonia	Sulphate of Potash
1	Complete Artificials (I) less Nitrogen	1·0	—	0·4	0·1	0·5	—	0·2
2	Unmanured	—	—	—	—	—	—	—
3	Complete Artificials	1·0	—	0·4	0·1	0·5	0·2	0·2
8	Complete Artificials with Dung	1·0	7	0·4	0·1	0·5	0·2	0·2
9	Complete Artificials less Phosphate	1·0	—	—	0·1	—	0·2	0·2
10	Complete Artificials less Potash	1·0	—	0·4	—	0·5	0·2	—

* The Top-dressing was applied in eight equal instalments.

APPENDIX "D"

DATES OF CULTURAL OPERATIONS, 1952

Crop	Sown	Potted into 60's	Potted into 32's	Planted out in Borders	First top Dressing	First Fruit Picked	Last Feed Applied	Last Fruit Picked
Tomatoes	3.1.52	28.1.52	—	1.3.52	16.4.52	19.5.52	14.8.52	28.10.52
Cucumbers	11.1.52	—	31.1.52	25.2.52	28.3.52	26.3.52	21.8.52	18.9.52

APPENDIX "E"

METEOROLOGICAL RECORDS, 1952

Month	Air Temperatures									Rainfall				Mean Soil Temperatures at 9 h. G.M.T.		Hygrometer at 9 hrs. G.M.T.				No. of Days Fog at 9 h. G.M.T. †	Bright Sunshine	
	Mean		Absolute Maximum		Absolute Minimum		No. of Ground Frosts*	Absolute Grass Min.		Total ppt.	No. of days ppt.	Greatest Fall				Dry Bulb	Depres. of Wet Bulb	Relative Hum'ty	Dew Point		Total Hours	Daily Av'ge
	Max.	Min.	Temp.	Date	Temp.	Date		Temp.	Date			Amt.	Date	4 ins.	8 ins.							
	°F.	°F.	°F.		°F.			°F.		Ins.		Ins.		°F.	°F.	°F.	°F.	%	°F.			
JANUARY ...	43·7	34·5	54	15th	21	27th	15	15	{27th 28th	1·99	16	0·36	4th	36·5	37·8	37·4	1·6	84·9	33·1	1	78·6	2·5
FEBRUARY ...	45·4	31·6	54	29th	25	{16th 17th	20	20	{5th 16th	0·60	11	0·20	10th	35·6	36·6	37·2	1·6	84·1	32·4	2	72·3	3·8
MARCH	51·5	38·1	60	3rd	28	27th	9	20	{15th 27th	2·94	18	0·73	29th	42·1	42·8	44·0	2·1	83·3	38·8	2	85·7	2·8
APRIL	60·4	41·2	75	{19th 30th	28	3rd	7	20	3rd	1·15	14	0·24	6th	47·9	47·9	52·4	4·2	71·7	43·2	0	184·7	6·1
MAY	67·9	47·1	82	18th	38	{22nd 30th	0	31	{22nd 30th	1·77	10	1·18	4th	60·2	57·4	59·6	5·4	69·1	48·9	0	214·2	6·9
JUNE	70·0	49·5	86	30th	37	8th	0	31	8th	1·30	12	0·24	6th	61·1	60·4	61·9	6·7	63·9	48·5	0	218·2	7·3
JULY	74·4	54·8	89	1st	44	16th	0	36	16th	0·65	3	0·26	3rd	66·5	66·2	65·5	6·9	64·4	52·4	0	206·5	6·7
AUGUST	71·5	54·5	78	6th	46	{22nd 23rd	0	39	29th	2·86	11	0·80	6th	62·4	62·3	64·1	5·0	73·0	55·0	0	190·2	6·1
SEPTEMBER ...	61·6	44·3	74	1st	34	{20th 28th	3	26	20th	3·08	17	1·08	30th	52·7	54·3	54·3	3·5	77·1	47·2	0	140·1	4·7
OCTOBER ...	56·0	42·0	61	6th	29	{12th 15th 16th	8	23	12th	2·22	16	0·60	12th	46·5	48·0	49·0	2·6	81·2	43·4	2	100·6	3·2
NOVEMBER ...	45·5	34·3	56	{2nd 10th	19	25th	15	12	25th	3·41	16	0·76	21st	38·5	40·5	39·9	1·8	84·7	35·5	2	68·0	2·3
DECEMBER ...	44·4	33·0	53	23rd	21	{6th 7th	22	12	5th	2·38	19	0·49	16th	35·2	36·3	37·8	1·0	90·3	33·9	10	47·9	1·5
TOTAL ...							99			24·35	163									19	1604·3	

* Grass Min. 30·4 ° F. or less.

† Visibility 440 yards or less.

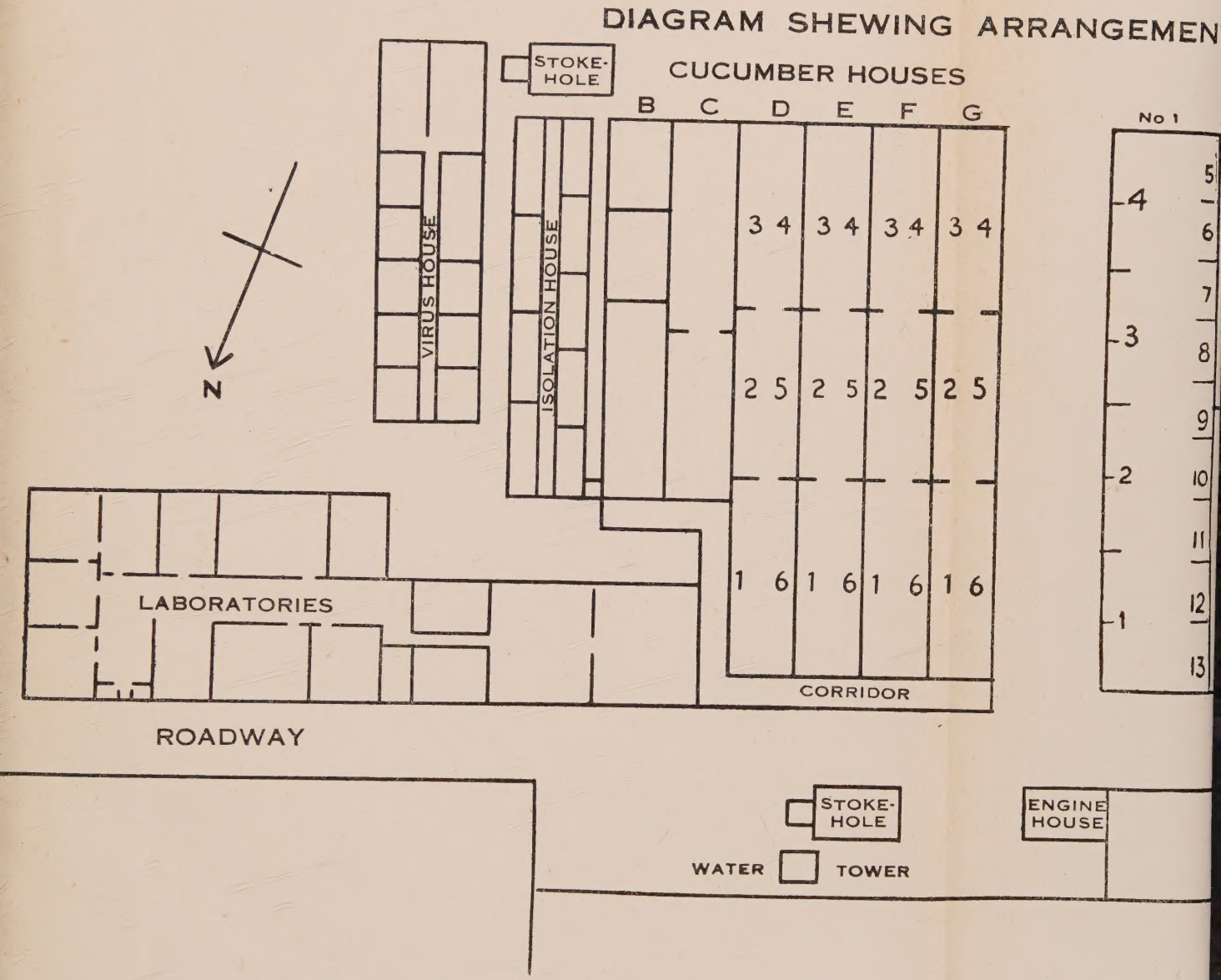
DIAGRAM SHEWING ARRANGEMEN
STOKE-HOLE
CUCUMBER HOUSES
B C D E F G
No 1
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3 4 3 4 3 4 3 4
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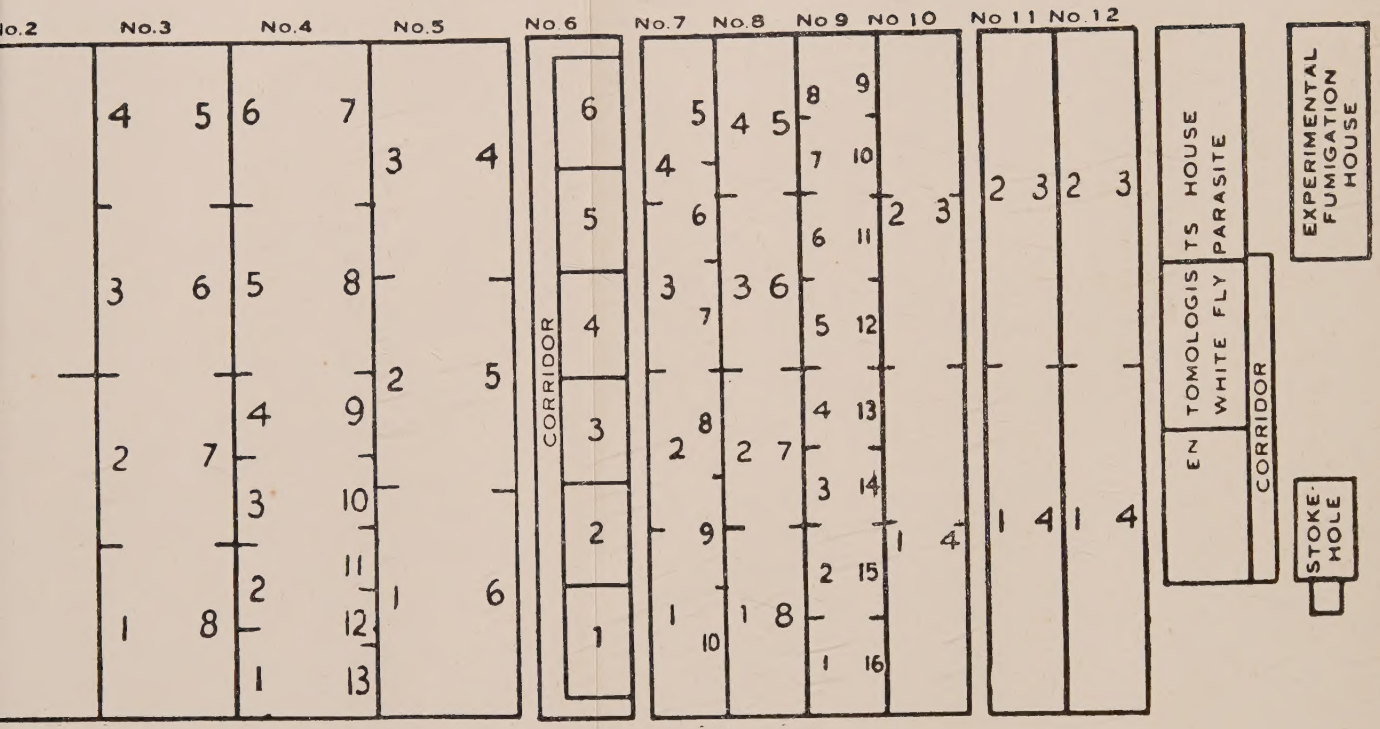
5 6 7 8 9 10 11 12 13
LABORATORIES
CORRIDOR
ROADWAY
STOKE-HOLE
ENGINE HOUSE
WATER TOWER

OF EXPERIMENTAL PLOTS, 1952

TOMATO HOUSES



ROADWAY

SHRUBBERY